

A Portfolio of Investigations

By John Green

Chemistry



John Green
Sadru Damji

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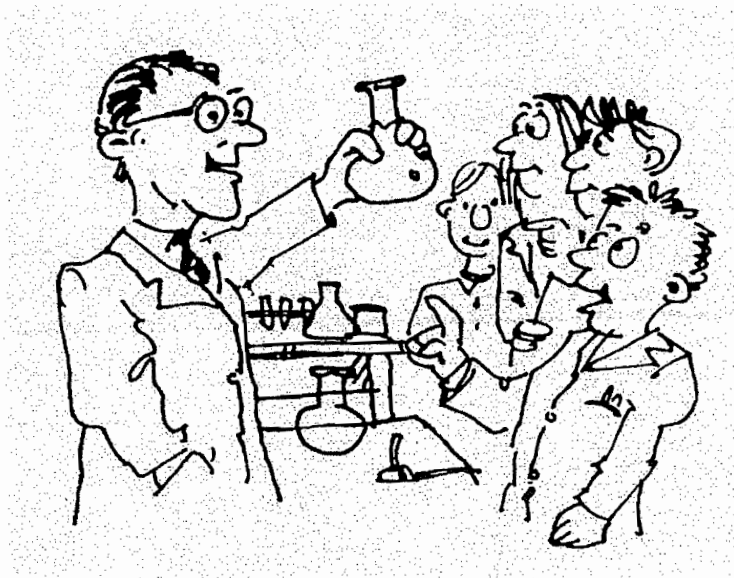


A PORTFOLIO OF INVESTIGATIONS IN CHEMISTRY

(for use with the IB Diploma programme)

(relevant to SSC)

Photocopy Masters

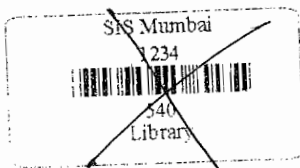


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Author: Dr John Green
Series editor: David Greig

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Publishing Information

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David Greig has worked very closely with each of the authors as editor in developing this series of Investigations for IB Science subjects. He is a Science education consultant, a graduate of the University of Adelaide and a very experienced Science teacher and author. Both the authors and David would be pleased to receive comments and suggestions about this publication from I.B. colleagues throughout the world and can be contacted (via 'S.T.A.R.') as given below:

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This document includes a series of **Investigations** as Photocopy Masters and a set of **Teaching Notes** which may be copied for use within the purchasing school and will assist in the preparation of materials and safe and productive conduct of the Investigations.

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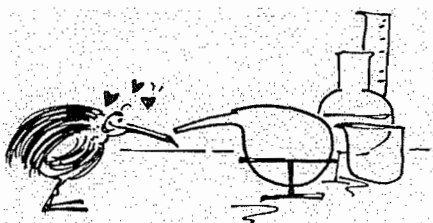
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Author Profiles

Dr John Green has been involved with the IB since joining Kristin School, New Zealand, in 1987, after extensive teaching experience in the UK at Repton and Manchester Grammar School. There, as IB coordinator, he was responsible for the introduction of the IB into the school, the first in New Zealand to offer the programme. John is involved in IB Chemistry as an assistant examiner at HL and previously at SL, as a setter of examination questions and, under the previous programme, he was overall moderator for the SL practical programme. In this role he was involved in a small way with the production of the new syllabus. At various times John has been present at both Chemistry and Final Grade Award meetings and has run a number of IB Chemistry workshops in the region. John also teaches Theory of Knowledge and is an assessor for the course. In 1996 John moved to Hong Kong where he is currently Director of Studies at the Li Po Chun United World College. He is the co-author of the "Chemistry for use with IB" text which is published by IBID Press in Australia.

David Greig has worked very closely with each of the authors (through cyberspace) as editor in developing this series of Portfolios of Investigations for IB Science subjects. He is the principal consultant of S.T.A.R., a graduate of the University of Adelaide and a very experienced Science teacher and author. Both John and David would be pleased to receive comments and suggestions about this publication from IB colleagues throughout the world and can be contacted (via S.T.A.R.) at the addresses given.

Acknowledgements

Whilst one or two of these practicals have been specially developed for this publication, the vast majority have been refined during my years of teaching at Repton, Manchester Grammar, Kristin and Li Po Chun. I would therefore like to thank my colleagues at these institutions and the students I taught for their many invaluable observations. I would also like to thank David Greig, the Series editor, for the numerous helpful comments that improved the initial drafts. I am truly grateful to my daughters Kirsty Alison and Katy for being understanding about my not always being as available as I should have been, and particularly to my wife Ann who not only supported me throughout the venture, but helped by word processing the last few sections when I was ill. I would however like to mainly dedicate this volume to my parents, Dorothy and Fred, who from an early age cultivated my natural curiosity, encouraged me to seek rational explanations and suffered with good humour my early chemistry experiments on top of the gas cooker. It is to them that I owe my enthusiasm for practical science that I hope is reflected in this book.

A Portfolio of Investigations for I. B. Chemistry

Foreword

This '*Portfolio of Investigations*' has been written specifically to support the teaching of the current **International Baccalaureate Chemistry Course** (©1996). It has been written by an experienced and practising Senior Chemistry teacher with very close reference to the *Internal Assessment* publication for I.B. Experimental Sciences.

This series of 30 Investigations provides a coverage of topic areas from the **SSC** (Subject Specific Core) and a selection of Type A, B, C and D activities as required by the assessment guidelines. This Portfolio begins with some preliminary investigations appropriate for students entering the course with little or no knowledge of practical Chemistry. The Investigations in this volume will fit comfortably into a '**Practical Scheme of Work**', as required but they are not intended to be exclusive or exhaustive. Additional collections of Investigations are currently being developed specifically for use with the **AHL** (Additional Higher Level) material and with the Options. A table is provided showing the relevant topics and suggested assessment focus for each Investigation. This set of Investigations will provide approximately 40-50 hours of activity. Each practical activity includes an Assessment table which is designed to record the teacher's judgement of the level achieved using the scale of 0-3. It also provides the opportunity for teachers to indicate the breakdown of these marks. There is also a Master Assessment table which may be used to maintain a progressive record to help determine the final score out of 24 as required. We would like to **acknowledge** the helpful advice given by various IBO staff in developing this series of Portfolios. We also wish to thank IBO for permission to include assessment 'Aspects' in the Teaching Notes for easy reference by teachers.

The authors have trialed all of these activities and have suggested various safety precautions but will not accept any responsibility whatsoever for any accident that may arise during the conduct of these Investigations. We will however be pleased to receive any suggestions and comments from staff or students using this material.

A second volume of Investigations for IB Chemistry is in preparation and will be published before the end of 1999. Please refer to www.ibid.com.au for current information.

Dr John Green (Author)

David Greig (Editor)

Hong Kong 2001

Theory of Knowledge

“Theory of Knowledge is central to the International Baccalaureate Diploma programme of studies. It may be seen as a matrix in which the distinct forms of knowledge specific to the subjects which comprise the IB curriculum can be critically evaluated, compared and contrasted and to an appropriate degree integrated.” (Ref: IB THEORY OF KNOWLEDGE GUIDE)

Participation in the IB Chemistry practical programme enables students to develop an understanding of the traditional ‘scientific method’. It requires students to become proficient in the process of experimental design. This includes key scientific concepts such as writing hypotheses, identifying and controlling variables, making detailed observations, collecting and analysing data and evaluating procedures.

By developing an understanding of the ‘scientific method’, students are able to compare this process with data collection in other subjects. Students can consider whether science is unique or whether the same or similar methods are used in mathematics and the social sciences.

Various other issues are incorporated into this practical programme. The use of models to develop an understanding of scientific concepts is considered in a number of investigations. Students are required to evaluate the use of their models and their role in the collection of scientific knowledge.

The differences between objectivity and subjectivity are inherent in any scientific investigation. Students are encouraged to take this into account when they interpret the data collected from detailed observations during these practical investigations. They need to evaluate the accuracy of their measurements and show how this impacts on their hypotheses. The human element in the interpretation of data and the making of conclusions is never far from the front in any of these investigations.

This IB Chemistry practical programme therefore encourages students to ‘see how science is done’. For a brief period they can imagine they are scientists collecting data and discovering new concepts. They can see how scientific knowledge is expanded, clarified and consolidated. By evaluating their own procedures and objectivity, they can cast some light on the factors, which influence ‘real’ scientists and how those factors can impact on their conclusions.

The teacher who has prepared this Portfolio of Investigations did so to assist students to develop a coherent ‘Theory of Knowledge’.

We trust that you will find these Investigations both enjoyable and valuable.

Portfolio of Investigations for IB Chemistry Outline Plan

No.	Practical	Topic	Hours	Pl(a)	Pl(b)	DC	DPP	Ev	MS
1.	The Separation of Mixtures - a Revision Exercise	P	2						
2.	The Preparation of a Soluble Salt	P	2						
3.	The Preparation and Properties of Some Common Gases	P	1						
4.	Purifying a Substance by Recrystallisation	P	1½						
5.	Tests for Anions and Cations	P	2						
6.	Determining the Water of Crystallisation	1	1						
7.	Determining the Composition of "Copper Carbonate"	1	1						
8.	How Concentrated is "Concentrated" Nitric Acid?	1	1½						
9.	The Solubility of Ethanedioic (Oxalic) Acid	1	2½						
10.	Determining the Molar Mass of a Soluble Acid	1	2						
11.	Percentage of Nitrogen Content in a Fertilizer	1	2						
12.	Finding the Percentage of Lead in Solder	1	1						
13.	Observing Emission Spectra	2	1						
14.	Some Reactions of the Halogens (Group 17)	3	1½						
15.	Structure and Physical Properties	4	2						
16.	Forces Between Particles	4	1						
17.	Changes of State	5	1½						
18.	Measuring Melting and Boiling Points	5	1						
19.	Measuring Enthalpy Changes	6	1						
20.	Using Hess' Law to Determine Enthalpy Changes	6	1						
21.	Techniques for Measuring Reaction Rates	7	2						
22.	A Quantitative Investigation of Reaction Rates	7	2½						
23.	Factors Affecting Rates of Chemical Reactions	7	1½						
24.	An Introduction to Equilibrium	8	½						
25.	Predicting the Effect of Changes on an Equilibrium	8	1½						
26.	A Comparison of Strong and Weak Acids and Bases	9	2						
27.	Common Oxidants and Reductants	10	1½						
28.	Some Reactions of Hydrocarbons	11	1						
29.	Investigating Organic Structures using Models	11	1						
30.	The Preparation of a Liquid Alkene	11	2						
	Total		45	6	7	13	15	13	10

IB Sciences Assessment Tables

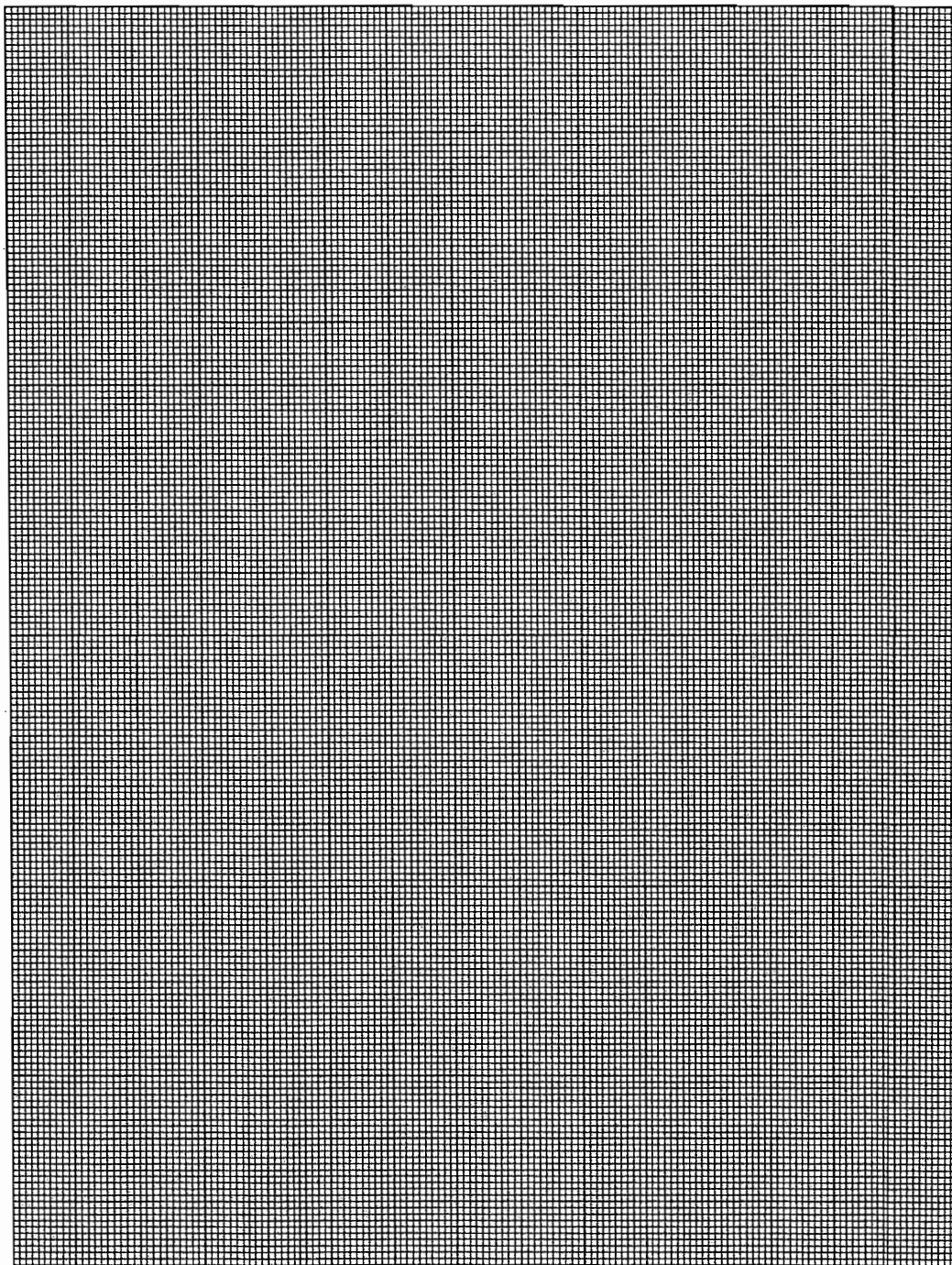
<i>Skills</i>	<i>Criteria</i>	<i>Complete (C) Partial (P) Not at all (N)</i>	<i>Level (0-3)</i>
Planning (a)	<ul style="list-style-type: none"> Defining a problem or research question Relating the hypotheses or prediction to the research question Selecting relevant variables 		
Planning (b)	<ul style="list-style-type: none"> Designing a method with appropriate apparatus/materials Designing a method for the control of the variables Designing a method for the collection of sufficient data 		
Data Collection	<ul style="list-style-type: none"> Collecting and recording appropriate raw data Presenting raw data allowing easy interpretation 		
Data Processing & Presentation	<ul style="list-style-type: none"> Processing raw data correctly Presenting processed data appropriately 		
Conclusion and Evaluation	<ul style="list-style-type: none"> Stating a valid conclusion based on interpretation of results Evaluating the procedure including limitations and errors Suggesting a modified procedure to improve the investigation 		
Manipulative Skills	<ul style="list-style-type: none"> Using techniques and equipment in a safe manner Following instructions accurately and thoughtfully 		
Personal Skills (a)	<ul style="list-style-type: none"> Working as part of a team Recognising the contribution of others Encouraging the contribution of others 		
Personal Skills (b)	<ul style="list-style-type: none"> Showing self-motivation and perseverance Behaving in an ethical manner Paying due attention to environmental impact 		

To the student

The study of Science is not merely a matter of memorising facts or even understanding and applying concepts, it also is a way of investigating or finding out about living and non-living materials. This is why all of the IB science subjects include the teaching and assessment of skills. The skills involve activities that would normally be undertaken by scientists and all other people who work in a scientific way. As you can see from the Assessment Table above, these skills can be broken down into specific criteria as shown by the 'dot points'. The activities in this Portfolio of Investigations will enable you to develop the skills and your teacher will assess whether you are able to demonstrate the criteria are 'Completely', 'Partially' or 'Not at all'. Your teacher will record this information and award a Level (0, 1, 2, or 3) for each skill. Since there are 8 skills you will be able to achieve a maximum of 24 points. You may wish to keep up a progressive record on the next page. If you need to know more about this process please ask your teacher.

None of the Investigations in this Portfolio focus specifically on Personal Skills criteria, but they will be subject to ongoing evaluation by your teacher(s) throughout your practical programme.

The next two pages are provided for you to copy for use in some of the Investigations if you wish.



[illegible]

HEALTH AND SAFETY SYMBOLS

Laboratories can be hazardous places. Often scientists, science teachers and students handle equipment and materials, which can be dangerous to their health and safety. Throughout these Portfolios of Investigations you will see a number of symbols which will represent particular hazards. For each of these we will briefly describe the hazard and indicate what precautions you might take to avoid damage and/or what responses are appropriate. In all cases of course, you should seek advice and assistance from the teacher or laboratory technician.



A *biohazard* is any organism or body fluid which could possibly cause illness or disease in your body. These particularly include micro-organisms. A particular hazard is using blood or blood products or saliva which may carry HIV, hepatitis or other diseases. In many cases it will be necessary for you to wear gloves and or devices which filter the air you breathe. Particular care should be taken when disposing of these materials.



A *flammable* substance is one which will readily burn in air. It may be a solid liquid or a gas. If you are using such a substance it is vital that there are no sparks or naked flames which could ignite it. It is vital that you know what to do in the event of fire. This may include the use of fire extinguishers and evacuation procedures.



A *radioactive* substance is one which emits particles or "radiation". This radiation is known to cause damage to cells and is known to be cancer causing. If you are using radioactive substances it is vital that you wear protective clothing, use metal tongs and listen carefully to instructions given by a teacher or laboratory technician.



Sharp instruments are often used in science and particularly in biology to cut sections through plant or animal tissue. These instruments which include scalpels and razor blades are very sharp and obviously will also cut through your tissues. When using these it is essential that you always cut away from your body and preferably on to a cutting board of some type. It is also important to be very careful when carrying these instruments and they also need to be placed on the workbench in a safe place.



Sometimes certain chemicals when mixed together become *explosive*. An explosion is caused by rapid expansion of gas in a confined space and can be very dangerous. Sometimes it is important to ensure that the space is not confined and sometimes it is important to conduct these reactions behind a protective screen.



Your eyes are the most vulnerable and easily damaged external part of your body. This is why they must be protected if you are using solids and liquids that could get into them. Whenever you are heating things, using corrosive liquids and in other cases as instructed by a teacher you should wear *safety goggles*. You should also do this if possible even if you wear spectacles to correct. You should also do this if possible even if you wear spectacles to correct you should wear safety goggles your vision. In the event that something gets in your eye anyway you should immediately make use of eyewash facility in the laboratory as instructed and then notify your teacher.



Sometimes it is necessary to protect your hands from heat, chemicals or other hazards and *gloves* will be made available. The type of glove needed will depend on the particular hazard and your teacher will provide further advice. In some case you will be advised to dispose of the gloves after use and in other cases to wash and dry them carefully.



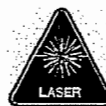
Some chemicals which are used in a laboratory are *corrosive*. This means that they can react with and 'eat away' materials like the bench, your books, clothing and skin. It is essential that you handle these materials which are usually liquids with care. Always tip from the container with the label uppermost, never add water to concentrated acid and never have your face anywhere near the container. It is usually advisable to wear both safety goggles and gloves. If protective aprons are available you should also wear one.



As a general rule 12 or 24 volt *electrical* appliances are unlikely to cause injury. However 'mains' voltage (110V or 240V or higher) can cause serious injury or death. The appliances you use should be regularly tested and certified safe. If you notice sparks or smell insulation burning turn the power off and notify staff. Be particularly careful not to allow water to get into any appliance as it may cause a short circuit.



Some chemicals are *poisonous* and should not be inhaled or ingested. It will be necessary to use a fume cupboard when using poisonous gases or volatile liquids. They could make you very ill and you may require medical assistance. It is vital that you listen to and follow instructions carefully and notify your teacher immediately if there is accidental exposure to poisonous or toxic substances.



Lasers are very intense beams of light. They are capable of causing burns to the skin and permanent damage to the eyes. It is essential that these are only ever used under the supervision of a teacher and in a situation where people can not see the beam directly or when it is reflected from a shiny surface. Sunglasses or welding masks do not provide sufficient protection and special 'laser glasses' must be used where there is a risk.



There are other *dangers* or hazards as well, for example carrying heavy or hot objects. This may also include chemicals which are not poisonous but which may smell unpleasant or irritate the skin. Whenever you see this icon more information will be provided in the adjacent text.

DISCLAIMER

The author, editor and publisher wish to declare that whilst all care has been taken in the preparation of these safety symbols, the advise above and their use in the Investigations, they can accept no responsibility whatsoever for any damage to property or injury to any person as a result of any accident or incident in the conduct of the activities in this book or other books in this series.

Date _____ Name _____

Investigation 1

THE SEPARATION OF MIXTURES - A Revision Exercise

This is a simple practical exercise designed to familiarise you with the thought processes involved in planning a practical.

ASSESSMENT

This practical will be assessed for *Planning (a)* on your answers to the planning section, for *Planning (b)* on the method you propose and for *Conclusion and Evaluation* on your reflections as to how well the method worked and ways in which it could be improved.

Planning (a)	• Defining a problem or research question		
	• Relating the hypotheses or prediction to the research question		
	• Selecting relevant variables		
Planning (b)	• Designing a method with appropriate apparatus/materials		
	• Designing a method for the control of the variables		
	• Designing a method for the collection of sufficient data		
Conclusion and Evaluation	• Stating a valid conclusion based on interpretation of results		
	• Evaluating the procedure including limitations and errors		
	• Suggesting a modified procedure to improve the investigation		

PLANNING

The object of this practical is to separate a mixture, comprising 5g each of two finely divided solids, making use of the fact that one is soluble in a particular solvent where as the other is insoluble in that solvent. Bearing this in mind you need to select from the list of available materials provided by your teacher:

Solid A _____ Solid B _____ Solvent _____

Describe in outline what you propose to do and how you expect to be able to separate the mixture to give the two pure components, explaining the principles upon which this depends.

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How much solvent will you use? _____ cm³

1. What would be the problem with using too little?

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2. What would be the problem with using too much?

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3. Will it be possible to tell during the course of the practical whether you have too much or too little solvent?

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4. What technique will you use to separate the solid from the solution and why is this preferable to the alternatives?

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5. Are there any precautions you will take to ensure that the insoluble solid is not contaminated with the soluble one?

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6. How will you recover the soluble solid from the solution? Are there any precautions necessary?

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METHOD

Weigh out accurately about 5g of Solid A and record it's mass. Repeat this for Solid B. Put both solids into a test tube and shake it to thoroughly mix them.

Now, referring back to your answers in the planning section, write a detailed method (giving the precise piece of apparatus to use, the amounts of substances required etc.) to separate the mixture.

This image shows a full page of white paper with horizontal dotted lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting practice. There are no margins, text, or other markings on the page.

Weigh accurately the amount of solid A recovered and record this in the space below.

Repeat for Solid B.

DATA COLLECTION

Initial mass g

Final mass g

Solid A _____

1000

Solid B

8

Other observations

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DATA ANALYSIS and EVALUATION

Calculate the percent of both Solid A and Solid B that were recovered.

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Assuming these are less than 100%, at what stages do you think the solids were lost?

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How might you modify your method to give better yields of the separated solids?

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Could your proposal have any undesirable consequences?

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Investigation 2

THE PREPARATION A SOLUBLE SALT

This is an exercise in planning and in preparative chemistry. The objective is to devise a method to produce a high yield of a pure salt from the reaction of an insoluble metal, metal oxide or metal carbonate, with an acid and then to put this into practice.

ASSESSMENT

This practical will be assessed for *Planning (b)* on the practicability of the method you suggest, *Conclusion and Evaluation* on your assessment of its success and suggestions for improvement and *Manipulative Skills* on how well you carry this out in practice.

Planning (b)	• Designing a method with appropriate apparatus/materials		
	• Designing a method for the control of the variables		
	• Designing a method for the collection of sufficient data		
Conclusion and Evaluation	• Stating a valid conclusion based on interpretation of results		
	• Evaluating the procedure including limitations and errors		
	• Suggesting a modified procedure to improve the investigation		
Manipulative Skills	• Using techniques and equipment in a safe manner		
	• Following instructions accurately and thoughtfully		

METHOD

You will have to write your own method overleaf giving full practical details of amounts, concentrations, times apparatus to be used etc. Some of the questions that you will have to ask yourself are:

1. What salt am I going to make and therefore which acid shall I use?
2. Would it be best to use the metal, its oxide or its carbonate?
3. If one reagent is going to be in excess, which will be easier to separate from the product? [A reasonable excess of one reagent is often preferable as otherwise the reaction rate can become very slow when almost all of both reagents are consumed.]
4. What concentration of acid should I use? How should I safely dilute the acid provided? [Concentrated acids are dangerous and may react at an undesirably fast rate, very dilute acids will be bulky and will react very slowly.]
5. What quantities of reagents should I use (remembering the excess)?
6. How should I measure the reagents out - what is an appropriate degree of precision?
7. What type of vessel should I react them together in? What size?
8. How will I know if the reaction is occurring at a reasonable rate?
9. What will I do if the reaction rate is too fast/too slow?
10. How will I know when the reaction is complete, i.e. all the limiting reagent is consumed?
11. How will I separate off the excess reagent?
12. How will I obtain the soluble salt from the solution?
13. What vessel should this be done in? What size?
14. How will I know when enough water has been removed? [Too little water and impurities may also crystallise, overheating may result in decomposition of the salt and in some cases, the salt may not be able to form its crystalline hydrate. Too much water and few, if any crystals will form.]
15. How will I remove the product and calculate the yield?

16. Is there any way to assess the purity of the product?

METHOD

Bearing the above questions in mind, write your Method in this space.

[illegible]

DATA COLLECTION

Mass of solid reagent used = _____ g

Mass of final product = _____ g

Volume of acid used = _____ cm³Concentration of acid used = _____ mol dm⁻³

Observations during the course of the reaction:

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DATA ANALYSIS and EVALUATION

- a) What was the maximum possible mass of product you could obtain, based on the amount of limiting reagent taken? What percentage of this did you attain?

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- b) Do you have any evidence regarding the purity of your product?

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- c) What parts of your practical do you think limited (i) the yield of product?

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- (ii) the purity of the product?

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- d) In what way do you think you could improve on your procedure, or the clarity of your practical instructions, if you were to repeat this investigation?

[illegible]

Investigation 3

PREPARATION AND PROPERTIES OF SOME COMMON GASES

You will prepare three different gases and each member of the group should carry out at least one of the preparations. The purpose of the experiment is to familiarise yourself with some of the most common gases encountered in chemistry, a simple preparation method for each and a test to identify them.

ASSESSMENT

This practical will be assessed for *Data Collection* on the accuracy of the observations that you make during the practical.

Data	• Collecting and recording appropriate raw data		
Collection	• Presenting raw data allowing easy interpretation		

METHODS

Warnings Use protective equipment and take care

**Hydrogen**

1. Put a few pieces of magnesium ribbon into a test tube and then add dilute hydrochloric acid to $\frac{1}{4}$ fill the test tube.
2. Test the gas evolved with moist red litmus paper and moist blue litmus paper.
3. Take a lighted splint, put your thumb over the end of the test tube to contain the gas for a few seconds and then insert the splint.
4. Repeat this using a glowing splint rather than a lighted splint.

Oxygen

1. Put about $\frac{1}{4}$ spatula of manganese (IV) oxide into a test tube.
2. Add 1 mol dm^{-3} aqueous hydrogen peroxide to give a depth of $\sim 1 \text{ cm}$.
3. Test the gas evolved with moist red litmus paper and moist blue litmus paper.
4. Test the gas inserting first a lighted and then a glowing splint into the mouth of the test tube.

Carbon dioxide

1. Put a few marble chips into the bottom of a test tube and then $\frac{1}{4}$ fill it with dilute nitric acid.
2. Test the gas evolved with moist red litmus paper and moist blue litmus paper.
3. Test the gas with both a lighted and a glowing splint, as above.
4. In a boiling tube put about a 1 cm depth of "limewater" (saturated aqueous calcium hydroxide).
5. Keeping the boiling tube vertical, put the mouth of the test tube over that of the boiling tube and tilt it a little, but not so much that any acid pours out.
6. Shake the boiling tube and observe the limewater.
7. Bubble carbon dioxide from a cylinder through the limewater and observe.
8. Finally heat up the boiling tube of limewater with a Bunsen burner.

If time allows, place a few marble chips in two more test tubes and add dilute hydrochloric acid to one and dilute sulfuric acid to the other.

DATA COLLECTION and ANALYSIS

- a) Record as accurately as possible what you observed when the hydrochloric acid was added to the magnesium. Apart from things you saw, were there any other changes that you noticed?

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- b) What occurred when the lighted splint was put into the gas? What about the glowing splint? Can you explain this?

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- c) Write balanced chemical equations for the reactions occurring.

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- d) Could anything else have been used to replace

(i) the magnesium?

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(ii) the hydrochloric acid?

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(iii) How else might these changes have affected the reaction? Explain.

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- e) What did you observe when the hydrogen peroxide was added to the manganese (IV) oxide?

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- f) What happened when the lighted and glowing splints were inserted into the gas evolved? Can you explain why this occurred?

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- g) Write a balanced equation for the reaction occurring.

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- h) What role does the manganese (IV) oxide play in this reaction?

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- i) Describe the reaction that occurs between the marble chips and the nitric acid.

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- j) Write a balanced chemical equation for the reaction of the marble chips and nitric acid.

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- k) What does the way the gas was transferred to the boiling tube show about the gas?

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- l) Describe the changes that occurred in the appearance of the limewater at the various stages of the reactions involving it.

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m) Explain these changes giving appropriate balanced equations.

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n) Describe the ways in which the reactions with hydrochloric acid and sulfuric acid were similar to, and the ways in which they differed from that with nitric acid. How could you account for the similarities and differences?

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o) Record the reactions of the different gases with the different colour litmus paper and the splints, both glowing and lit, in a suitable manner.

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Investigation 4

PURIFYING A SUBSTANCE BY RECRYSTALLISATION

This practical is designed familiarise you with the technique of recrystallisation, which is frequently used to purify compounds, especially organic compounds.

ASSESSMENT

This practical will be assessed for *Manipulative Skills* on the amount of your product and its quality, as assessed by the colour and dryness. It will also be assessed for *Conclusion and Evaluation* on your assessment of the practical method used, factors that limited its success and ways in which you could have improved the amount and quality of your product.

Manipulative Skills	• Using techniques and equipment in a safe manner		
	• Following instructions accurately and thoughtfully		
Conclusion and Evaluation	• Stating a valid conclusion based on interpretation of results		
	• Evaluating the procedure including limitations and errors		
	• Suggesting a modified procedure to improve the investigation		

METHOD

In this technique a solvent is chosen in which the solubility of the desired compound increases with temperature. The impure compound is dissolved in a small volume of the hot solvent and any insoluble impurities filtered off. The hot solution is then allowed to slowly cool and the compound will crystallise out (hopefully!), leaving soluble impurities in solution. (The slower the formation of crystals the purer the product.) The crystals can then be filtered off, preferably by suction filtration, and a final rinse with a little cold solvent removes the last traces of impurity before drying the product.

****Remember - recrystallisation is an art, not a science!****



- 1 Take your sample of the impure organic compound, weigh it and dissolve it completely in hot water in a conical flask. You will need to find the correct amount by trial and error - start with about 10 cm³ of water and heat it up to about its boiling point for a minute or two, but do not boil vigorously. If the soluble components of the mixture have not all dissolved, then add a little more water and heat again. Repeat this, until you have a hot concentrated solution, but if it is too concentrated you may have problems in the next stage!
- 2 Filter off any insoluble impurities. This must be done rapidly so as to prevent crystals forming in the funnel. This will be a particular problem if you have too little solvent. Using a fluted filter paper will help rapid filtration. Collect the filtrate in a clean conical flask.
- 3 If crystals start to form, reheat the solution until they redissolve and then place it on one side to cool slowly. If the crystallisation is still too rapid or complete you may want to add a little more solvent and heat the mixture up again. While you are waiting, set up the apparatus for suction filtration.
- 4 When the solution has cooled sufficiently, filter off the product using suction filtration and then rinse the crystals with a little cold water.
- 5 Leave air being sucked through your product in the funnel until the product is dry - spreading it out evenly over the filter paper with a spatula will help speed up the process.
- 6 When the crystals are dry, transfer them to a weighed vial and record the yield. Stopper the vial, label it and hand it in for inspection.

DATA COLLECTION

	Mixture	Product
Mass of container and product	= _____ g	= _____ g
Mass of container	= _____ g	= _____ g
Mass of solid	= _____ g	= _____ g

DATA ANALYSIS and EVALUATION

a) Calculate your yield as a percentage of the mass of mixture taken and enter below.

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Percentage yield of recrystallised product = _____ %

b) How would you try and solve the following potential problems?

(i) When you cool the solution, the whole mixture turns solid, rather than crystals separating.

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(ii) When you cool the solution, no crystals separate.

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- c) There are a number of places in the technique where yield must be balanced against purity.

Identify some of these and explain the dilemma.

[illegible]

- d) A fluted filter paper and suction filtration are both techniques that are useful in recrystallisation.

Explain how these work as well as the advantages and disadvantages of each.

[illegible]

Investigation 5

TESTS FOR ANIONS AND CATIONS

This Investigation is in two parts. In the first part, you will familiarise yourself with reactions that are useful to identify common anions and cations. In the second part you will be test some unknown substances to try and identify the ions present in them.

ASSESSMENT

This practical will be assessed for *Data Collection* on the observations you make and *Data Processing and Presentation* on the conclusions you draw about the unknown substances.

Data	• Collecting and recording appropriate raw data		
Collection	• Presenting raw data allowing easy interpretation		
Data Processing &	• Processing raw data correctly		
Presentation	• Presenting processed data appropriately		

Warnings Some of these chemicals are hazardous and you should wear protective clothing and take care

Part A



METHOD, DATA COLLECTION and ANALYSIS

For each test record what changes were observed and the explanation for these, including relevant equations.

Carbonate

Put a small amount of the substance in a test tube. Add dilute nitric acid a little at a time and test any gas evolved with limewater.

Observation

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Explanation

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Sulphate

Put about a 1 cm depth of the solution in a test tube and add an equal volume of dilute nitric acid. Now add a few drops of aqueous barium chloride or barium nitrate.

Observation

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Explanation

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Chloride

Put about a 1 cm depth of the solution in a test tube and add an equal volume of dilute nitric acid. Now add a few drops of aqueous silver nitrate.

Observation

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Explanation

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Magnesium

Put about a $\frac{1}{2}$ cm depth of the solution in a test tube and add a few drops of aqueous sodium hydroxide. Next add more aqueous sodium hydroxide to a depth of about 3 cm and stir.

Observation

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Explanation

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Aluminium

Put about a $\frac{1}{2}$ cm depth of the solution in a test tube and add a few drops of aqueous sodium hydroxide. Next add more aqueous sodium hydroxide to a depth of about 3 cm and stir.

Observation

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Explanation

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Iron(II)

Put about a $\frac{1}{2}$ cm depth of the solution in a test tube and add a few drops of aqueous sodium hydroxide. Next add more aqueous sodium hydroxide to a depth of about 3 cm and stir.

Observation

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Explanation

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Iron(III)

Put about a $\frac{1}{2}$ cm depth of the solution in a test tube and add a few drops of aqueous sodium hydroxide. Next add more aqueous sodium hydroxide to a depth of about 3 cm and stir.

Observation:

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Explanation

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Copper

Put about a $\frac{1}{2}$ cm depth of the solution in a test tube and add a few drops of aqueous sodium hydroxide. Next add more aqueous sodium hydroxide to a depth of about 3 cm and stir.

Observation:

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Explanation

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Silver

Put about a $\frac{1}{2}$ cm depth of the solution in a test tube and add a few drops of aqueous sodium hydroxide. Next add more aqueous sodium hydroxide to a depth of about 3 cm and stir.

Observation:

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Explanation

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Part B

In this part of the practical you will be given various solids, labelled with letters. Each is a salt that contains one anion **and** one cation from those investigated in Part A.

Dissolve a little of your solid in water (about 1 spatula full in 25 cm³ of distilled water in a 100 cm³ beaker) and use this solution to test for the ions. If it does not dissolve in water, add dilute nitric acid, noting any reaction, and then use this solution for the tests, remembering that it will require significantly more aqueous sodium hydroxide to form a precipitate than an aqueous solution would.

For each substance write down the reactions that you do ("Test"), what happens ("Observation") and what it tells you about the substance ("Inference") and from these identify the anion and cation present.

Substance ____ **Anion -** _____ **Cation -** _____

Test	Observation	Inference

Substance ____ **Anion -** _____ **Cation -** _____

Test	Observation	Inference

Substance _____ Anion - _____ Cation - _____

Test	Observation	Inference

Substance _____ Anion - _____ Cation - _____

Test	Observation	Inference

Substance _____ Anion - _____ Cation - _____

Test	Observation	Inference

Investigation 6

DETERMINING THE WATER OF CRYSTALLISATION

In this practical you will determine the number of moles of water of crystallisation in crystals of a hydrated salt by heating it to constant mass in a crucible.

ASSESSMENT

This practical will be assessed for *Data Processing and Presentation* on the accuracy with which you compute the final result from your experimental data, as well as for *Conclusion and Evaluation* on your assessment of your results and possible errors in the method used and suggestions for improvements.

Data Processing & Presentation	• Processing raw data correctly		
	• Presenting processed data appropriately		
Conclusion and Evaluation	• Stating a valid conclusion based on interpretation of results		
	• Evaluating the procedure including limitations and errors		
	• Suggesting a modified procedure to improve the investigation		

Warnings Some of these chemicals are hazardous and you should wear protective clothing and take care

**METHOD**

- 1) Weigh an empty crucible with its lid and record the result as accurately as possible below.
- 2) Approximately one-third fill the crucible with crystals of the salt that you have been assigned, replace the lid and then reweigh.
- 3) Heat the crucible strongly on a pipeclay triangle for about ten minutes and then leave it to cool.
- 4) When it is cool enough to hold in your hand, reweigh it.
- 5) Heat for a further five minute, again leave to cool and reweigh.
- 6) Repeat 5) until there is no further loss in weight.

DATA COLLECTION

Mass of empty crucible and lid = _____ \pm _____ g

Mass of crucible, lid and hydrated salt = _____ \pm _____ g

Mass of crucible and salt after first heating = _____ \pm _____ g

Mass of crucible and salt after second heating = _____ \pm _____ g

Mass of crucible and salt after third heating = _____ \pm _____ g

Mass of crucible and salt after fourth heating = _____ \pm _____ g

DATA ANALYSIS and EVALUATION

- a) Calculate the mass, and hence the number of moles, of anhydrous salt that remained, using the molar mass of the anhydrous salt you used.

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- b) Calculate the mass, and hence the number of moles, of water that was lost from the salt.

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- c) Hence calculate the number of moles of water that are combined with one mole of the salt.

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- d) The number of moles should be an integer. Bearing this in mind, what was the formula of the hydrated salt?

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- e) What was the precision of your weighings? Use this to calculate the possible error that this introduces into your estimate of the moles of water of crystallisation.

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- f) If your result was less than the accepted value, what experimental errors could explain this?

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- g) If your result was greater than the accepted result, what experimental errors could be the cause of this?

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h) Why was the crucible cooled before weighing?

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i) After the crucible is cool, the weighing should be carried out as rapidly as possible. Why is this?

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j) Why was the crucible heated with the lid on?

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k) In what ways could you suggest changing the technique used in order to significantly improve the accuracy of the result?

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l) This technique cannot be used to determine the water of crystallisation present in all salts. Why might a particular salt be unsuitable? Give some specific examples if you can. Have you any suggestions of how it could be determined in these cases?

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Investigation 7**DETERMINING THE COMPOSITION OF 'COPPER CARBONATE'**

Commercial copper carbonate is actually a mixture of copper carbonate and copper hydroxide. Both of these decompose on heating to form copper oxide. If commercial copper carbonate is heated to constant mass, the proportions of the carbonate and hydroxide may be calculated from the loss in mass.

ASSESSMENT

This practical will be assessed for *Manipulative Skills*, on the accuracy of your results and on the skill displayed in handling the apparatus.

Manipulative Skills	• Using techniques and equipment in a safe manner		
	• Following instructions accurately and thoughtfully		

Warnings Some of these chemicals and techniques are hazardous and should be used with care

**METHOD**

- 1) Weigh an empty crucible with its lid and record the result below as accurately as possible.
- 2) Approximately one-third fill the crucible with copper carbonate, replace the lid and then reweigh.
- 3) Heat the crucible strongly on a pipeclay triangle for about ten minutes and then leave it to cool.
- 4) When it is cool enough to hold in your hand, reweigh it.
- 5) Heat for a further five minute, again leave to cool and reweigh.
- 6) Repeat 5) until there is no further loss in weight.

DATA COLLECTION

Mass of empty crucible and lid	= _____ ± _____ g
Mass of crucible, lid and carbonate	= _____ ± _____ g
Mass of crucible after first heating	= _____ ± _____ g
Mass of crucible after second heating	= _____ ± _____ g
Mass of crucible after third heating	= _____ ± _____ g
Mass of crucible after fourth heating	= _____ ± _____ g

DATA ANALYSIS and EVALUATION

- a) Calculate the mass loss that would have occurred if the solid had been pure copper carbonate.

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- b) Calculate the mass loss that would have occurred if the solid had been pure copper hydroxide.

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- c) Calculate the weight loss that you actually observed - hopefully it is between the two figures that you calculated in a) and b).

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- d) If the substance was x% copper carbonate, calculate the weight loss that you would expect and then solve for x by equating this to the observed weight loss.

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- e) What do you consider to be the major limiting factor in the accuracy of this determination?

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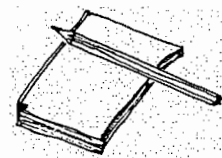
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DATA COLLECTION

Mass of weighing bottle & sodium carbonate = _____ g

Mass of weighing bottle after emptying = _____ g

Volume of concentrated nitric acid used = _____ cm³which was diluted to _____ cm³

Titration No.	Rough	1	2	3
Final reading (cm ³)				
Initial reading (cm ³)				
Titre (cm ³)				

Volume of Na₂CO₃ taken = _____ cm³Average titre = _____ cm³**DATA ANALYSIS and EVALUATION**

- a) Use your weighings to calculate the concentration of the sodium carbonate solution.

Mass of sodium carbonate used = _____

Moles of sodium carbonate used = _____

Concentration of solution = _____

- b) Use your titration results to calculate the concentration of the diluted nitric acid, and hence of the concentrated acid.

Equation for the reaction _____

Moles of sodium carbonate pipetted out = _____

Moles of nitric acid this reacted with = _____

Concentration of diluted nitric acid = _____

Concentration of original nitric acid = _____

- c) Were your titration results all exactly the same? If not, why not?

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d) How did you try to improve on the accuracy of the titration result?

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e) There would also have been inaccuracies in making up the standard solution. What were these?

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f) Which of these do you think would have been the more significant? How would these have compared with the inaccuracies in the titration?

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g) Apart from these, what other sources of inaccuracy could there have been? How significant do you think these might have been? How could you check this?

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h) If you had to improve the accuracy of the technique, what one change would have most effect?

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i) The titration was sometimes carried out in a flask that was wet with distilled water. Does this affect the accuracy? Explain why.

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j) If you wanted to make 2 dm³ of 2 M nitric acid, what volume of the concentrated acid would you dilute?

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k) If the concentrated nitric acid has a density of 1.42 g cm⁻³, what is the concentration of water in the concentrated acid? (HINT - calculate the mass of acid in 1 dm³ and hence the mass of water in there)

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Date _____ Name _____

Investigation 9

THE SOLUBILITY OF ETHANEDIOIC (OXALIC) ACID

This practical is designed to provide an opportunity for you to demonstrate your planning skills in relation to gravimetric and volumetric analysis.

ASSESSMENT

This practical will be assessed for *Planning (b)*, on your written instructions about how to carry out the practical - what pieces of apparatus to use, what concentrations of reagents to employ etc. The results you record and the way in which these are presented will be assessed for *Data Collection*.

This investigation will also be assessed for *Conclusion and Evaluation* based upon the way in which you consider the two techniques that you suggest and identify their weaknesses in them, as well as the retrospective suggestions you have for ways in which your chosen method could be improved.

Planning (b)	• Designing a method with appropriate apparatus/materials		
	• Designing a method for the control of the variables		
	• Designing a method for the collection of sufficient data		
Data Collection	• Collecting and recording appropriate raw data		
	• Presenting raw data allowing easy interpretation		
Conclusion and Evaluation	• Stating a valid conclusion based on interpretation of results		
	• Evaluating the procedure including limitations and errors		
	• Suggesting a modified procedure to improve the investigation		

PLANNING

The object of this practical is to determine the solubility of ethanedioic acid. This acid is available as the white crystalline dihydrate $[(\text{COOH})_2 \cdot 2\text{H}_2\text{O}]$. Its solubility at room temperature is about 10 g dm^{-3} . It is a weak dibasic acid ($\text{pK}_a = 1.23$ and 4.28) and a mild reducing agent (when warmed it will reduce acidified aqueous potassium permanganate).

Warning Ethanedioic acid and its salts are poisonous



You should propose **two** contrasting methods (i.e. ones that are based on different physical/chemical principles and hence have different inherent errors in them) to measure the solubility and write a brief outline of both of these methods. You should then explain which one of these you feel would yield the most reliable results - this is where most of the evaluation marks will be earned.

For this method you should then write a detailed practical procedure. It should for example state what apparatus to use precisely, (i.e. a 10 cm^3 measuring cylinder, not just a measuring cylinder) what solutions to use (giving the concentrations - you will probably have to do some calculations to check these are appropriate) and how to proceed (again in detail).

Outline of method 1

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Outline of method 2

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Comparison of the methods

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The method chosen for detailed planning is method _____.

METHOD (use extra paper as required)

DATA COLLECTION

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DATA ANALYSIS and EVALUATION

a) Use your results to calculate the solubility of ethanedioic acid in g dm^{-3} .

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b) What would you estimate to be the probable precision of this value?

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c) What were the major factors limiting the accuracy of your determination? How could you modify the method used to improve the precision?

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Investigation 10

DETERMINING THE MOLAR MASS OF A SOLUBLE ACID

In this practical you will be required to determine the molar mass of a soluble organic acid by titration against a solution of sodium hydroxide, which you have standardised using potassium hydrogen phthalate as the primary standard.

ASSESSMENT

This practical will be assessed for *Planning (b)* on the method that you submit, for *Data Collection* on the way in which you record your experimental data and for *Manipulative Skills* on the accuracy of your final result.

Planning (b)	• Designing a method with appropriate apparatus/materials		
	• Designing a method for the control of the variables		
	• Designing a method for the collection of sufficient data		
Data Collection	• Collecting and recording appropriate raw data		
	• Presenting raw data allowing easy interpretation		
Manipulative Skills	• Using techniques and equipment in a safe manner		
	• Following instructions accurately and thoughtfully		

Warning Please take care, some of these chemicals and techniques are hazardous



METHOD

You will be provided with:

Solid potassium hydrogen phthalate (a primary standard that acts as a soluble monobasic acid, M_r of $\text{KHC}_8\text{H}_4\text{O}_4 = 202.4$)

Aqueous sodium hydroxide (approximately 0.1 mol dm^{-3})

Solid "Acid X" (the soluble acid whose molar mass you are to find)

Phenolphthalein indicator

You will also have available all of the usual apparatus for volumetric analysis, i.e. volumetric flasks, pipettes, burettes etc.

You must write your own experimental method for the practical.

This should include details of *precisely* what apparatus to use (i.e. "a 100 cm^3 volumetric flask" rather than just "a volumetric flask") and specify the amounts of the reagents to be used. You will also need to decide what measurements you need to take and produce a suitable results section for recording these. This practical method must be written overleaf and handed in before the practical:

METHOD (use extra paper as required)

DATA COLLECTION

Record your results in an appropriate form

DATA ANALYSIS

- a) Calculate the concentration of the aqueous sodium hydroxide.

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- b) Assuming "Acid X" to be monobasic, calculate the molar mass of the acid.

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- c) If your burette reading in the titration of "Acid X" with the aqueous sodium hydroxide had been in error by 0.1 cm^3 , what difference would this have made to your final estimate of the molar mass?

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- d) Suppose that "Acid X" had been tribasic. What value of the molar mass would you then obtain? How could you find out the basicity of the acid and hence the correct molar mass?

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- e) Potassium hydrogen phthalate is being used as the **primary standard**. What properties must a primary standard have and why is sodium hydroxide itself not suitable?

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Investigation 11

PERCENTAGE OF NITROGEN IN A FERTILISER

This practical is designed to analyse a fertiliser for ammonium ions by reaction with a known excess of aqueous sodium hydroxide, followed by back titration with hydrochloric acid to determine how much of the alkali remains unreacted. The concentration of the sodium hydroxide is only approximately known, as it absorbs carbon dioxide from the air, therefore the alkali is standardised by direct titration with the hydrochloric acid.

ASSESSMENT

This practical will be assessed for *Conclusion and Evaluation* on your discussion of the methods employed and for *Manipulative Skills* on the accuracy of your results.

Evaluation	• Evaluating (interpreting) results (drawing conclusions)		
	• Evaluating procedure(s)		
	• Modifying the procedure		
Manipulative Skills	• Carrying out a range of techniques in a safe manner		
	• Following a variety of instructions		

Warning Please take care, some of these chemicals and techniques are hazardous



METHOD

- 1) Weigh out accurately about 2 g of the fertiliser into a weighing bottle. Carefully transfer the solid to a 250 cm³ conical flask, ensuring that none spills, then accurately reweigh the empty weighing bottle.
- 2) Pipette out 25 cm³ of 2 mol dm⁻³ aqueous sodium hydroxide into the 250 cm³ conical flask. Gently boil the flask and its contents until the vapour evolved no longer smells of ammonia, nor turns moist red litmus paper blue. Observe the flask regularly and add small amounts of distilled water so as to keep the total volume of liquid approximately constant.
Do not allow the flask to boil dry!
- 3) Fill the burette with the 1 mol dm⁻³ hydrochloric acid. Add a little bromothymol blue indicator to the contents of flask and titrate with the hydrochloric acid.
- 4) Repeat 1), 2) and 3) until consistent results are achieved.

Step 5 may be carried out before, during, or after parts 1) to 4).

- 5) Pipette out 10 cm³ of 2 mol dm⁻³ aqueous sodium hydroxide into a 100/150 cm³ conical flask. Add a little bromothymol blue indicator to the contents of flask and titrate with the 1 mol dm⁻³ hydrochloric acid. Repeat until consistent results are achieved.

DATA COLLECTION**Weighings**

Titration No.	1	2	3	4
Mass of weighing bottle and fertiliser (g)				
Mass of empty weighing bottle (g)				
Mass of fertiliser (g)				

Back titration

Titration No.	1	2	3	4
Final reading (cm ³)				
Initial reading (cm ³)				
Titre (cm ³)				

Standardisation titration

Titration No.	Rough	1	2	3
Final reading (cm ³)				
Initial reading (cm ³)				
Titre (cm ³)				

Average titre = _____ cm³

DATA ANALYSIS and EVALUATION

- a) Use the results from the standardisation titration to calculate the concentration of the aqueous sodium hydroxide.

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- b) Use this result to calculate the number of moles of sodium hydroxide used to dissolve each sample of the fertiliser.

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Carry out c) and d) separately for each sample of the fertiliser.

- c) Use the titration results to calculate the moles of sodium hydroxide that were in excess and hence the number of moles that reacted with the fertiliser.

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- d) Use this result to calculate the mass of nitrogen in the sample of the fertiliser assuming that one mole of sodium hydroxide reacts with one nitrogen atom.

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- e) The percentage **nitrogen** (by mass) is usually quoted on fertiliser bags. What should the fertiliser be labelled, according to your analysis?

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- f) What assumption have you made about the form in which the nitrogen was present in the fertiliser?

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- g) Why was a back titration technique used?

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- h) Why was the solution boiled?

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- [illegible]

- [illegible]



Investigation 12**FINDING THE PERCENTAGE OF LEAD IN SOLDER**

In this practical you will learn how to use a precipitation reaction for gravimetric analysis.

ASSESSMENT

This practical will be assessed for *Data Processing and Presentation* on the calculation of the result from the data obtained and the assessment of the accuracy of this value. It will also be assessed for *Conclusion and Evaluation* on your assessment of the technique, probable sources of error and suggestions for improvements.

Data Processing & Presentation	• Processing raw data correctly		
	• Presenting processed data appropriately		
Conclusion and Evaluation	• Stating a valid conclusion based on interpretation of results		
	• Evaluating the procedure including limitations and errors		
	• Suggesting a modified procedure to improve the investigation		

Warning Please take care, some of these chemicals and techniques are hazardous

**METHOD**

- 1) Weigh a 250 cm³ conical flask, add about 10 g of solder and then reweigh it.
- 2) Add 100 cm³ of 2 mol dm⁻³ nitric acid from a measuring cylinder and leave the flask in a fume cupboard overnight.
- 3) By the next day the solder should have dissolved. If there is any solid residue or cloudiness, carry out 4), otherwise if the liquid is clear go straight to 5).
- 4) Warm the liquid to ~60°C and then filter into a clean 250 cm³ conical flask. Rinse the flask twice with ~10 cm³ of distilled water and then pour this through the filter paper, collecting the liquid in the same flask as the filtrate.
- 5) Add 50 cm³ of 2 mol dm⁻³ sulfuric acid to the liquid in the conical flask. Heat the flask to ~60°C.
- 6) Write your name in pencil on a piece of filter paper and then weigh it. Now fold it and place it in the filter funnel.
- 7) Filter the contents of the flask. Dilute 5 cm³ of 2 mol dm⁻³ sulfuric acid to 50 cm³ in a measuring cylinder. Use a 25 cm³ portion of this to rinse the flask and then pour this through the precipitate in the filter paper. Repeat this with the second 25 cm³ portion of the diluted acid.
- 8) Remove the filter paper from the funnel and place it in an oven at 130°C for at least two hours, but preferably overnight, then finally weigh the filter paper and filtrate.

DATA COLLECTION

Mass of flask & solder = _____ g

Mass of flask = _____ g

Mass of filter paper & precipitate = _____ g

Mass of filter paper = _____ g

DATA ANALYSIS

- a) Use your weighings to calculate the percent of lead in the solder.

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- b) What were the most probable sources of error in this determination and how might the procedure have been modified so as to minimise these inaccuracies?

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- c) Why was the precipitate washed with dilute sulfuric acid rather than water?

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- d) What other elements would you expect to be present in solder? Why is this better than using pure lead? What assumption does this analysis make about these elements?

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Date _____ Name _____

Investigation 13

OBSERVING EMISSION SPECTRA

In this practical you will observe emission spectra from various sources and account for the differences in their appearance.

ASSESSMENT

This practical will be assessed for *Data Collection* on your recording of your observations and for *Data Processing and Presentation* on your interpretation of these.

Data	• Collecting and recording appropriate raw data		
Collection	• Presenting raw data allowing easy interpretation		
Data Processing & Presentation	• Processing raw data correctly		
	• Presenting processed data appropriately		

METHOD

- 1) Look at a patch of daylight through the hand held spectroscope and record your observations. (**Do not** look directly at the sun!!!)
- 2) Now observe a tungsten filament light bulb and a fluorescent light tube through the spectroscope. How do they compare with the daylight and with each other?
- 3) If some discharge tubes have been provided, observe these through the spectroscope and record your observations.
- 4) Put a little dilute hydrochloric acid in one watch glass and a few crystals of sodium chloride in another. Take a Bunsen burner and starting with the air hole closed, just open it enough to make the flame colourless, but not so much as to create a blue central cone. Take a nichrome wire and pass it through the flame just quickly enough for it not to become red-hot. It should not colour the flame - if it does, heat it to red-hot and then quench it in the hydrochloric acid. Repeat this until the wire does not colour the flame.
- 5) Dip the nichrome wire into the acid and then into the sodium chloride. Pass the wire through the flame as before and observe the colour produced. Have another student do this whilst you observe the flame colour through the spectroscope.
- 6) Repeat this using the following instead of sodium chloride:

potassium chloride
copper(II) chloride

calcium chloride
lithium chloride

barium chloride
strontium chloride

In each case you should also replace the hydrochloric acid to prevent it becoming contaminated. Record the spectrum you observe for each substance.

DATA COLLECTION

For each source that you observed the spectrum of, record your observations in an appropriate way using words, sketches or a combination of these.

DATA ANALYSIS

- a) What is the relationship between the colour of light and the amount of energy carried by each photon of light?

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- b) The spectra you observed could be divided into two main types - what are these and what do they show about the amounts of energy being lost.

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- c) Explain the origin of the type of spectra observed in the discharge tubes and with the salts introduced into the Bunsen flame.

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- d) If instead of your eye, you had a detector that could detect radiation of a greater range of frequencies, what would you expect to find when observing sources such as the ones you have been using?

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- e) How has a quantitative study of atomic emission spectra contributed to our knowledge of atomic structure?

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- f) Under some circumstances absorption spectra can be observed. How would these arise and what would their appearance be?

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Investigation 14**SOME REACTIONS OF THE HALOGENS (GROUP 17)**

This practical is designed to investigate similarities in the chemical reactions of the halogens and some of their compounds.

ASSESSMENT

This practical will be assessed for *Data Collection* on the accuracy of the observations that you make and for *Data Processing and Presentation* your interpretation of them.

Data	• Collecting and recording appropriate raw data		
Collection	• Presenting raw data allowing easy interpretation		
Data Processing & Presentation	• Processing raw data correctly		
	• Presenting processed data appropriately		

Warning Please take care, some of these chemicals and techniques are hazardous

**METHOD**

Chlorine and bromine are both toxic and have an obnoxious odour, therefore try and carry out reactions 2, 3 and 4 in a fume cupboard, as far as is practicable.

- Test the solubility of iodine in each of the following, noting the colour of the solution as well as the solubility. (N.B. take a very small quantity of iodine initially)
 - water
 - ethanol
 - hexane (Caution - flammable)
 - aqueous sodium iodide
- Put a few drops of chlorine water on to a watch glass and test it with blue litmus paper. Repeat this firstly using bromine water and then iodine solution instead of the chlorine water.
- Put a 2 cm depth of bromine water into a test tube and then add aqueous sodium hydroxide a drop at a time until there is no further colour change. Now add dilute sulfuric acid until the colour change ceases.
- Put a 2 cm depth of aqueous sodium chloride, sodium bromide and sodium iodide into three separate test tubes and label these so that they can be identified. Add an equal volume of chlorine water to each test tube and note the result. Now add a little hexane to form a separate upper layer of a non-polar solvent. Shake the mixture and note the changes. Repeat, firstly using bromine water and then iodine solution instead of the chlorine water.
- Put about a 2 cm depth of aqueous sodium chloride into a test tube, add a little aqueous silver nitrate and record your observations. Now place the test tube in a sunny place, and leave it there for about ten minutes and then observe it again. Repeat using aqueous sodium bromide, then aqueous sodium iodide instead of the sodium chloride.
- Put a 2 cm depth of aqueous sodium chloride in a boiling tube and add aqueous lead (II) nitrate until a permanent precipitate forms - note its colour. Warm the mixture to boiling point and then leave it to slowly cool, observing it periodically. Repeat using sodium bromide and sodium iodide instead of the chloride.

DATA COLLECTION and ANALYSIS

For each part of the practical, record your observations and attempt to explain these results. This is deliberately 'open-ended', both in terms of observations and explanations.

Investigation 15 STRUCTURE AND PHYSICAL PROPERTIES

In this practical the chemical structure of certain substances will be explored by investigating the physical properties of the substances.

ASSESSMENT

This practical will be assessed for *Planning (a)* on the outline plan of your method for testing the substances, for *Planning (b)* on the practical details of the way in which you carry this out. It will also for *Conclusion and Evaluation* on your interpretation of the results, the limitation of your methods that you perceive and your suggestions for possible improvements.

Planning (a)	• Defining a problem or research question		
	• Relating the hypotheses or prediction to the research question		
	• Selecting relevant variables		
Planning (b)	• Designing a method with appropriate apparatus/materials		
	• Designing a method for the control of the variables		
	• Designing a method for the collection of sufficient data		
Conclusion and Evaluation	• Stating a valid conclusion based on interpretation of results		
	• Evaluating the procedure including limitations and errors		
	• Suggesting a modified procedure to improve the investigation		

PLANNING

You should have discussed the way in which the type of bonding present in substances affects their physical properties.

Describe in your own words what you hope to achieve as a result of this experiment:

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Outline what properties you intend to test and the information that you would expect to gain as a result of these tests:

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What factors will it be important to control during your investigation?

How vital will this control be?

[illegible]

METHOD

You will be provided with a number of solids, identified only by letters. You will also have water and a typical non-polar solvent available.

In the space below describe practical details of how you intend to test the various substances. These instructions should state exactly what apparatus to use, how much of the substances to take, give an accurate description of how the test is to be performed and what should be recorded.

[illegible]

DATA COLLECTION and ANALYSIS

[illegible]

EVALUATION

- a) For each of the substances that you investigated, state what overall conclusion you can reach with regard to its structural type, how certain you are of this and what further tests could be used to help remove any uncertainty.

[illegible]

- b) What limitations were imposed by the techniques used and how do you think these could have been overcome?

[illegible]

Date _____ Name _____

Investigation 16

FORCES BETWEEN PARTICLES

This practical is designed to investigate the forces between particles, how these affect the solubility of substances and changes that occur on mixing liquids, as a result of intermolecular forces.

ASSESSMENT

This practical will be assessed for *Data Collection* on the accuracy of the observations that you make and for *Data Processing and Presentation* your interpretation of these.

Data Collection	• Collecting and recording appropriate raw data		
	• Presenting raw data allowing easy interpretation		
Data Processing & Presentation	• Processing raw data correctly		
	• Presenting processed data appropriately		

METHOD and DATA COLLECTION

- Take a *small* amount of one of the solids listed in the bottom of two test tubes and then fill one to a depth of ~ 3 cm with hexane and the other to a similar depth with water. Stir and observe whether the solid appears soluble. (N.B. It is vital to use a *very small* amount of solid otherwise it will be difficult for you to see if it is slightly soluble.) Record your observations in the table below.



Solute / Solvent	Hexane	Water
Sodium chloride		
Urea		
Naphthalene		
Silicon dioxide		

- For each of the pairs of liquids in the table below, take exactly 5 cm³ of each in separate measuring cylinders and check they are at room temperature, which should be recorded (____ °C). Mix the liquids together and record whether they are miscible, what the total volume is and the temperature change (if any) on mixing.



Liquid A	Liquid B	Miscibility	Volume	Temp. Change
Ethyl ethanoate	Trichloro-methane			
Propanone	Water			
Ethanol	Hexane			
Water	Hexane			
Hexane	Hexene			

- Take the 3 tubes containing liquids and a bubble of air. Invert the tubes and compare the rates at which the bubbles rise in the tubes and grade them from the fastest to the slowest.

Fastest _____ Slowest _____

- 4) Working in a fume cupboard, take 5 burettes and fill them with the following liquids:
water, cyclohexane, trichloroethane, propanone, tetrachloromethane



Electrically charge a plastic rod by rubbing it on the material provided and bring it close to, but **not touching** a steady stream of liquid from the burette into a large beaker underneath. Observe whether the charged rod causes the stream of liquid to deviate from vertical.

Liquids that deviated because of the presence of the charged rod were:

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DATA ANALYSIS

- a) In the case of each solute explain, in terms of the intermolecular forces involved, its solubility in both solvents.

Sodium chloride in hexane

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Sodium chloride in water

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Urea in hexane

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Urea in water

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Naphthalene in hexane

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Naphthalene in water

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Silicon dioxide in hexane

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Silicon dioxide in water

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b) For each of the five mixtures explain as appropriate, in terms of intermolecular forces, why:

- they were miscible/immiscible
- there was/was not a change in the total volume on mixing.
- there was/was not a change in temperature on mixing.

ethyl ethanoate - trichloromethane

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propanone - water

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ethanol - hexane

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water - hexane

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hexane - hexene

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- c) What physical property of a liquid is mainly responsible for the rate at which a bubble moves through it?

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- d) How did the rate at which the bubble moved in hexane and paraffin compare? Explain why.

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- e) Why did the streams of some substances deviate from vertical?

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- f) Draw diagrams of the molecules involved and explain in terms of these why the liquid was deflected/undeflected.



Investigation 17

CHANGES OF STATE

These practicals explore changes of state and measurements connected with these.

ASSESSMENT

This practical will be assessed for *Data Processing and Presentation* on your interpretation of the results and for *Evaluation* on your assessment of the results, the practical methods used and ways in which these may be improved.

Data Processing & Presentation	• Processing raw data correctly		
	• Presenting processed data appropriately		
Conclusion and Evaluation	• Stating a valid conclusion based on interpretation of results		
	• Evaluating the procedure including limitations and errors		
	• Suggesting a modified procedure to improve the investigation		

Warning Please take care, some of these chemicals and techniques are hazardous.



METHOD

Part A - Melting

1. Weigh out 10 g of naphthalene put it in a test tube and place a thermometer in it.
2. Measure out 10 cm³ of water into a second test tube and place a thermometer in it.
3. Place both test tubes in a boiling water bath. When the contents of the test tubes have reached the temperature of the water bath, place them inside a boiling tube supported in a test tube rack.
4. Record the temperature of both test tubes every 30 seconds until they fall to 70°C.

Part B - Boiling

1. Set up some Quickfit apparatus for distillation with a thermometer going to the bottom of a 50 cm³ pear-shaped flask. Put 5 cm³ of methanol and a few anti-bumping granules into it.
2. Place the flask in a boiling water bath and record the temperature in the **bottom** of the distillation flask every 30 seconds until it reaches that of the water bath. Note when all of the methanol has boiled off.
3. Put about 50 cm³ of methanol and a few anti-bumping granules into a Buchner flask and fit this with a bung holding a thermometer.
4. Connect the flask to a filter pump and observe what happens.

DATA COLLECTION**Part A**

Naphthalene			
Time (s)	Temp (°C)	Time (s)	Temp (°C)
0		330	
30		360	
60		390	
90		420	
120		450	
150		480	
180		510	
210		540	
240		570	
270		600	
300		630	

Water			
Time (s)	Temp (°C)	Time (s)	Temp (°C)
0		330	
30		360	
60		390	
90		420	
120		450	
150		480	
180		510	
210		540	
240		570	
270		600	
300		630	

Part B

Methanol			
Time (s)	Temp (°C)	Time (s)	Temp (°C)
0		330	
30		360	
60		390	
90		420	
120		450	
150		480	
180		510	
210		540	
240		570	
270		600	
300		630	

Observations made on methanol in the Buchner flask:

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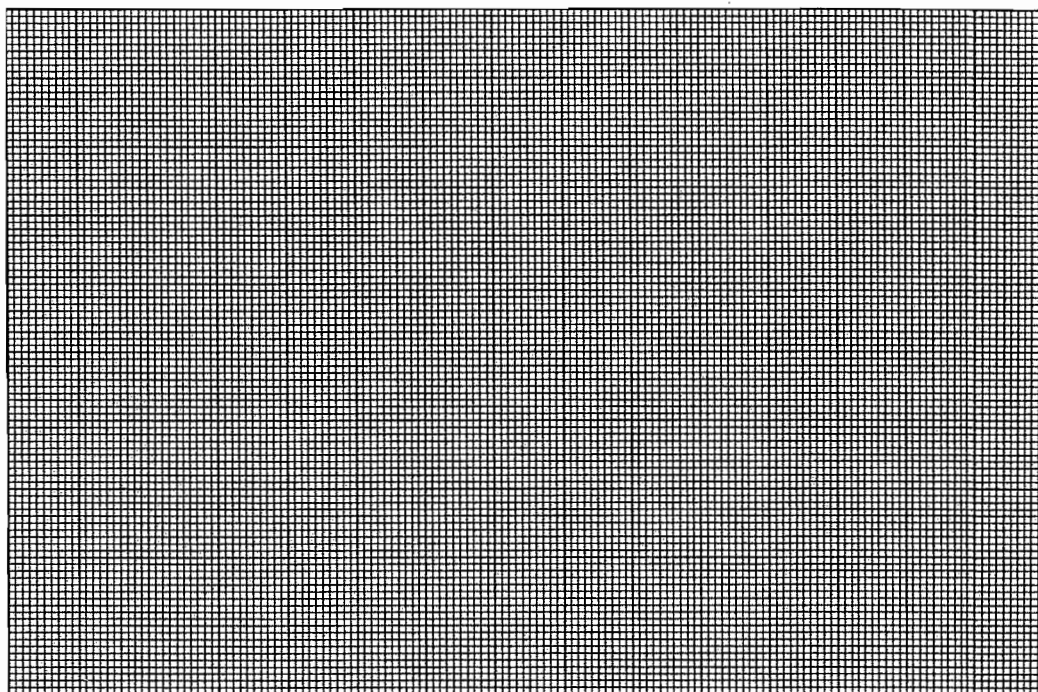
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DATA ANALYSIS and EVALUATION**Part A**

- a) Draw graphs of temperature against time for both sets of data using the same axes.



- b) Interpret the major features of the naphthalene graph.

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- c) Draw a tangent to the water graph at the melting point of the naphthalene, to determine the rate of cooling.

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- d) Taking the specific heat capacity of water as $4.184 \text{ JK}^{-1} \text{ g}^{-1}$, calculate the rate of heat loss (in Js^{-1}) from a test tube inside a boiling tube under these conditions.

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- e) From the graph, estimate the length of time required for the naphthalene to solidify. Use this to calculate the total heat lost in the process and hence the latent heat of fusion of naphthalene (C_{10}H_8) in J mol^{-1} .

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- f) What assumptions have you made in this determination and how valid do you consider these to be?

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- g) What were the limiting factors on the accuracy of this method and how might it be improved?

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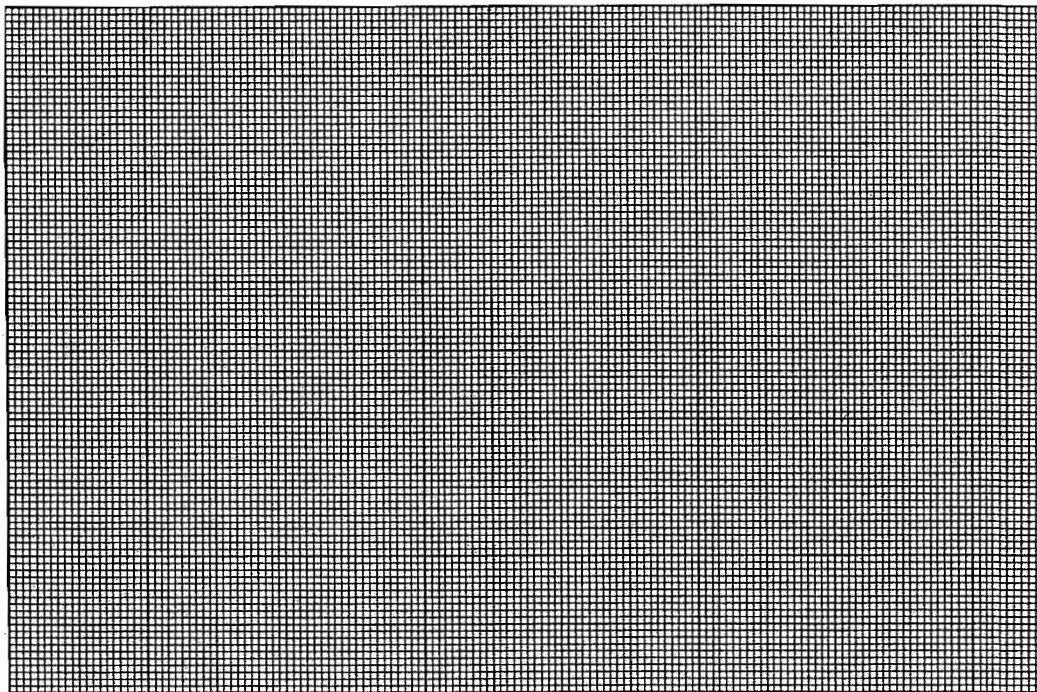
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Part B

h) Draw a graph of temperature against time for the methanol.



i) Interpret the major features of the graph.

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j) Explain your observations when the Buchner flask containing methanol was evacuated.

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Date _____ Name _____

Investigation 18

MEASURING MELTING AND BOILING POINTS

This practical is designed familiarise you with the measurement of these physical properties. They are both used as criteria of purity, especially for organic compounds, as melting points in particular are very sensitive to the presence of impurities.

ASSESSMENT

This practical will be assessed for *Planning (a)* on your discussion of the underlying theory behind the use of melting points to determine purity. It will also be assessed for *Manipulative Skills* on your appreciation of the precautions required in the methods used and the accuracy of your results.

Planning (a)	• Defining a problem or research question		
	• Relating the hypotheses or prediction to the research question		
	• Selecting relevant variables		
Manipulative Skills	• Using techniques and equipment in a safe manner		
	• Following instructions accurately and thoughtfully		

PLANNING

In the first part of this practical you will observe two samples of a substance melting, one of which is pure and the other of which is impure.

What will you be attempting to do?

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What do you hypothesise about the differences you will find?

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Hence what parameters will you measure and which variables will it be important to control?

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METHOD

There are various techniques for determining melting and boiling points, depending on the apparatus available. Your teacher will demonstrate the types of apparatus that you have available. You are then expected to record these methods in the space provided below, remembering to give details of precautions to be taken in order to obtain accurate results. Use these methods to observe the melting of samples A and B and to record the boiling point of liquid C.

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DATA COLLECTION

Melting of solid A

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Melting of solid B

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Boiling point of liquid = _____ \pm _____ $^{\circ}\text{C}$

DATA ANALYSIS

- a) What differences did you notice in the melting of the two samples of the organic solid? As a result, which do you consider to be the pure sample?

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- b) What factors limit the accuracy of your melting point determination? How could it be made more accurate?

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- c) How would you expect the boiling point determined to depend on the presence of impurities?

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- d) What factors limit the accuracy of your boiling point determination? How could it be made more accurate?

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Investigation 19

MEASURING ENTHALPY CHANGES

The object of this practical is to measure the heat evolved or absorbed in some physical and chemical changes.

ASSESSMENT

The practical will be assessed for *Conclusion and Evaluation*, with the emphasis being on the precision of your method, comments on the agreement between your results and the generally accepted values for these changes, as well as your suggestions for minimising this difference. It will also be assessed for *Manipulative Skills* based on how well you carry out this practical as reflected in the values you obtain.

Conclusion and Evaluation	• Stating a valid conclusion based on interpretation of results		
	• Evaluating the procedure including limitations and errors		
	• Suggesting a modified procedure to improve the investigation		
Manipulative Skills	• Using techniques and equipment in a safe manner		
	• Following instructions accurately and thoughtfully		

METHOD

Part A - The heat required for a change of state.

- 1) Put 100 cm³ of water at about 60°C into a polystyrene cup by mixing boiling water from the kettle with cold water from the tap.
- 2) Dry about 25 g of ice with a piece of paper towel and weigh them both.
- 3) Rapidly record the temperature of the water and transfer the ice to it, then record the mass of the paper towel and the water it has absorbed.
- 4) Stir the water ice mixture and record the temperature of the water as soon as all the ice has just melted.

Part B - Determining the enthalpy change for the displacement reaction between zinc and aqueous copper sulphate



- 1) Take a polystyrene cup and use a measuring cylinder to put 50 cm³ of 1 M aqueous copper (II) sulphate in it.
- 2) Weigh out accurately about 5 g of powdered zinc into a weighing bottle.
- 3) Stir and record the temperature of the copper sulphate at half minute intervals for 2 minutes and then add the powdered zinc.
- 4) Record the temperature at half minute intervals until the temperature has been falling for ten consecutive readings.

DATA COLLECTION**Part A**

Mass of ice, filter paper and water = _____ g

Mass of filter paper and water = _____ g

Initial temperature of water = _____ °C

Final temperature of water = _____ °C

Part B

Time (s)	Temp (°C)	Time (s)	Temp (°C)
0		330	
30		360	
60		390	
90		420	
120		450	
150		480	
180		510	
210		540	
240		570	
270		600	
300		630	

Mass of empty weighing bottle = _____ g

Mass of weighing bottle and zinc = _____ g

Precision of Measurements

Record the precision of the various measurements that you have made.

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DATA ANALYSIS and EVALUATION

In all of these experiments you will be measuring the heat gained or lost using the equation:

$\text{Heat change} = \text{mass} \times \text{specific heat} \times \text{temperature change}$

The heat changes will be mainly those used to heat/cool the water or aqueous solution and, unless you are instructed otherwise you may ignore the heat gained or lost by the calorimeter and the other substances present. Take the specific heat of water and dilute aqueous solutions as $4.183 \text{ kJ dm}^{-3} \text{ K}^{-1}$.

Part A

- a) Calculate the heat lost by the warm water.
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- b) Calculate the heat gained to raise the temperature of the molten ice to the final temperature.
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- c) Use these to calculate the heat required to melt the ice.
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- d) From this result calculate the latent heat of fusion of ice in kJ mol^{-1} .
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- e) Use your values for the precision of the readings to calculate the precision of this value
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- f) Look up the accepted value for the enthalpy of fusion of ice and compare it to the value you have determined.

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- g) What assumptions have been made in this determination? Is the true value likely to be greater or smaller than that measured. Explain.

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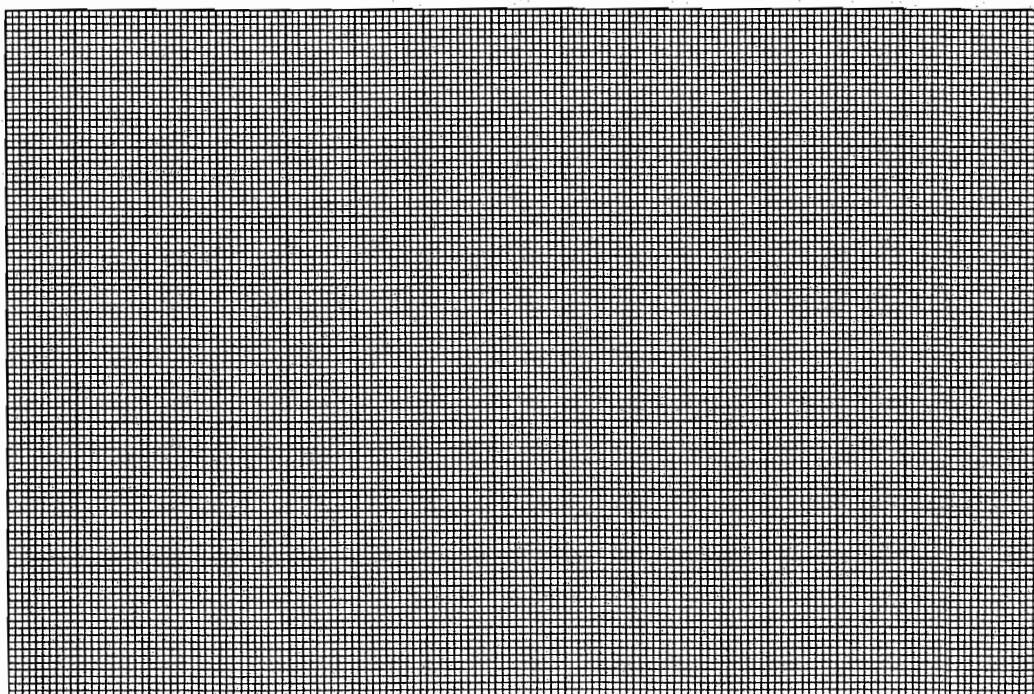
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Part B

- h) Plot a graph of temperature against time, including error bars, and draw the best straight line through initial section and the final cooling section.



Use this graph to estimate the rise in temperature that would have occurred if the reaction had been instantaneous and heat had not been lost to the environment.

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- i) Calculate the heat energy produced by the reaction.

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- j) Calculate which of the reagents is the limiting reagent.

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- k) From the number of moles of the limiting reagent calculate a value of ΔH for the reaction.

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- l) The accepted value for this is $\sim -210 \text{ kJmol}^{-1}$. Comment on the accuracy of your result and whether the discrepancy is in keeping with the major source of error of the method.

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- m) Suggest ways in which the accuracy of either, or both, of the determinations could be significantly improved

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Investigation 20

USING HESS' LAW TO DETERMINE ENTHALPY CHANGES

There are many reactions for which direct measurement of the enthalpy of reaction is difficult, the thermal decomposition of sodium hydrogencarbonate being such a reaction. In these cases it is often possible to determine the enthalpy of reaction by direct measurements on more accessible related systems and then applying Hess' Law. This practical illustrates this approach.

ASSESSMENT

The practical will be assessed for *Data Processing and Presentation* based on the way in which you calculate the result from the collected data and for the *Conclusion and Evaluation* on your assessment of the probable sources of error and suggestions for improvements in the method.

Data Processing & Presentation	• Processing raw data correctly		
	• Presenting processed data appropriately		
Conclusion and Evaluation	• Stating a valid conclusion based on interpretation of results		
	• Evaluating the procedure including limitations and errors		
	• Suggesting a modified procedure to improve the investigation		

Warning Please take care, some of these chemicals and techniques are hazardous



METHOD

- 1) Measure out, using a measuring cylinder, 100 cm³ of 2 mol dm⁻³ hydrochloric acid into an expanded polystyrene container of at least 250 cm³ capacity.
- 2) Weigh out accurately about 14 g of sodium hydrogencarbonate into a weighing bottle and record the mass used.
- 3) Record the temperature every 30 s. After the third reading start adding the solid to the acid - you may have to do this a little at a time otherwise the evolution of the gas may cause liquid to overflow.
- 4) Continue taking temperature readings until you have ten readings after the temperature has reached its maximum/minimum.
- 5) Repeat steps 1) to 4) but taking about 8g of anhydrous sodium carbonate, rather than the sodium hydrogencarbonate.

EVALUATION

- a) The accepted enthalpy change for the decomposition of sodium hydrogencarbonate is $+85 \text{ kJ mol}^{-1}$. How does your value compare with this?

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- b) What do you consider to be the major source of error in your determination of this value?

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- c) How could you modify the method used to increase the accuracy of the result?

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- d) What would be the difficulties in determining this enthalpy change directly?

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Investigation 21**TECHNIQUES FOR MEASURING RATES OF REACTIONS**

This practical allows you to gain experience in a number of techniques that can be used to measure the rate of a chemical reaction.

ASSESSMENT

This practical will be assessed for *Data Collection* on choosing suitable time intervals and recording data to an appropriate precision. It will also be assessed for *Data Processing and Presentation* on the way in which you represent and interpret the data collected and for *Manipulative Skills* on how well you handle the challenge of working with new equipment.

Data	• Collecting and recording appropriate raw data		
Collection	• Presenting raw data allowing easy interpretation		
Data Processing & Presentation	• Processing raw data correctly		
	• Presenting processed data appropriately		
Manipulative Skills	• Using techniques and equipment in a safe manner		
	• Following instructions accurately and thoughtfully		

Warning Please take care, some of these chemicals and techniques are hazardous

**METHOD**

This is quite a long practical, so it may be that different members of your group, or different groups, carry out different parts of it. If this is the case, take time to acquaint yourself with what other people are doing so as to gain an understanding of all of these techniques.

The separate sections may be carried out in any sequence.

Technique A Volume of Evolved Gas

- 1) Take a 250 cm³ conical flask fitted with a bung and a tube leading to a 100 cm³ gas syringe, with the barrel fully in.
- 2) Measure out, using a measuring cylinder, 40 cm³ of 0.5 mol dm⁻³ hydrochloric acid and put this into the flask.
- 3) Take a 4 cm³ long piece of magnesium ribbon. Drop it into the flask, replace the stopper immediately and start timing.
- 4) Record the volume of gas evolved at appropriate time intervals until the reaction ceases. Initially you will have to take readings quite frequently, but the time intervals can be increased as the reaction slows down.

Technique B Decrease in Mass

- 5) Measure out 100 cm³ of 2 mol dm⁻³ nitric acid, using a measuring cylinder and place this in a 250 cm³ conical flask.
- 6) Weigh out about 10g of marble chips on a piece of filter paper, then place the flask containing the acid alongside it on the balance and record the initial mass.
- 7) Start timing, tip the marble chips into the acid and put the filter paper under the flask. Place a loose fitting cotton wool stopper in the neck of the flask so that it does not 'spit' or froth over.

B Decrease in Mass

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C Titrating Samples

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D Light Absorption

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Present your results in an appropriate form and for each section use this to calculate the initial rate of reaction in convenient units. You may use graph paper (copy p8) and additional paper if required.

[illegible]

EVALUATION**A *Volume of Evolved Gas***

- a) What are the limitations in the types of reactions that can be studied in this way?

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- b) What are the advantages of this method?

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- c) What were the practical difficulties in applying this method?

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- d) What improvements could you suggest to overcome these?

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B *Decrease in Mass*

- e) What are the limitations in the types of reactions that can be studied in this way?

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- f) What are the advantages of this method?

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g) What were the practical difficulties in applying this method?

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h) What improvements could you suggest to overcome these?

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C *Titrating Samples*

i) What are the limitations in the types of reactions that can be studied in this way?

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j) What are the advantages of this method?

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k) What were the practical difficulties in applying this method?

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l) What improvements could you suggest to overcome these?

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D Light Absorption

m) What are the limitations in the types of reactions that can be studied in this way?

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n) What are the advantages of this method?

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o) What were the practical difficulties in applying this method?

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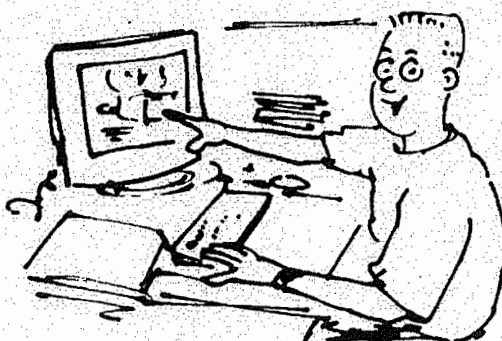
p) What improvements could you suggest to overcome these?

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Date _____ Name _____

Investigation 22

A QUANTITATIVE INVESTIGATION OF REACTION RATES

This practical gives you a chance to apply one of the methods of measuring reaction rates that you have already met, to planning your own quantitative study

ASSESSMENT

This practical will be assessed for *Planning (a)* on your responses to the planning section and for *Planning (b)* on the method that you produce for the practical. It will also be assessed for *Data Collection* on the results you choose to record and the way in which you recorded them.

Planning (a)	• Defining a problem or research question		
	• Relating the hypotheses or prediction to the research question		
	• Selecting relevant variables		
Planning (b)	• Designing a method with appropriate apparatus/materials		
	• Designing a method for the control of the variables		
	• Designing a method for the collection of sufficient data		
Data Collection	• Collecting and recording appropriate raw data		
	• Presenting raw data allowing easy interpretation		

PLANNING

You will firstly need to decide what reaction to measure the rate of, the technique going to use to measure it and the variable (temperature, concentration of a particular reagent, amount of catalyst, quantity of reagents etc.) you are going to change.

Reaction _____

Technique _____

Variable _____

Why have you chosen this particular technique to measure the rate?

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What difficulties could you encounter and what precautions may you need to take?

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How will you use the results to measure the initial rate ?

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Make a *quantitative* prediction (i.e. the initial rate will be directly proportional to the variable, inversely proportional to the square root of the variable etc.) of the way in which you expect the initial rate of change as you alter the variables.

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METHOD

Referring back to the planning section, write your own method for carrying out this practical giving precise details of apparatus to be used, quantities and concentrations of reagents etc.

This image shows a full page of white paper with horizontal dotted lines, typical of primary school handwriting practice paper. The lines are evenly spaced and run across the entire width of the page. There are no margins, text, or other markings on the paper.

[illegible]

Analyse your results in an appropriate manner and use these to find the initial rate under the different conditions. Then see if these rates do indeed vary in the way you predicted.

[illegible]

EVALUATION

a) Were you satisfied at the results the practical produced? Explain

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b) In what ways could your method have been changed so as to give more accurate results?

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c) Did your results confirm or refute the hypothesis that you made in the planning section?

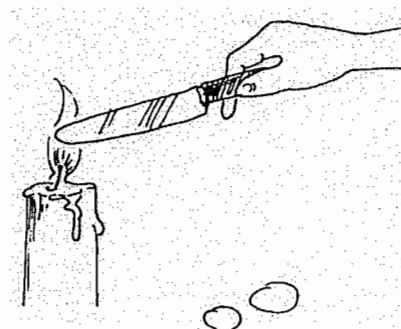
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Investigation 23**FACTORS AFFECTING RATES OF CHEMICAL REACTIONS**

This practical qualitatively investigates the factors that affect the rate of a chemical reaction and the way in which these effects may be explained in terms of collision theory.

ASSESSMENT

This practical will be assessed for *Data Processing and Presentation* on the presentation of your results and the interpretation of these in terms of appropriate theory.

Data Processing & Presentation	• Processing raw data correctly		
	• Presenting processed data appropriately		

Warning Please take care, some of these chemicals and techniques are hazardous

**METHOD**

Carry out Part A. You will then be assigned one of Part B to Part F to carry out.

Part A

- 1) Place a 250 cm³ conical flask on the balance and add about 10g of small lumps of calcium carbonate.
- 2) Measure out 50 cm³ of 5M hydrochloric acid (**CARE!** Nearly the same as the concentrated acid) using a measuring cylinder.
- 3) Place the measuring cylinder alongside the flask on the balance and record the total mass.
- 4) Add the acid to the flask and note the time. Record the total mass (remember to leave the empty measuring cylinder on the balance pan!) at half minute intervals, then one minute, two minute, and five minute intervals as the reaction slows down.

Part B

Repeat using 100 cm³ of 5M acid rather than 50 cm³.

Part C

Repeat using 25 cm³ of 5M acid and 25 cm³ of water instead of 50 cm³ of the acid.

Part D

Use 5g of calcium carbonate instead of 10g.

Part E

Warm the hydrochloric acid to 20°C above room temperature before adding the calcium carbonate.

Part F

Use one large lump of calcium carbonate, rather than a number of small lumps.

DATA COLLECTION

Initial mass of flask + acid and petri dish + calcium carbonate = _____ g

Record the mass of the total system at various times in the table below.

Time (s)	Experiment A Total Mass (g)	Experiment ____ Total Mass (g)	Time (s)	Experiment A Total Mass (g)	Experiment ____ Total Mass (g)
30			360		
60			420		
90			480		
120			540		
150			600		
180			720		
210			840		
240			960		
270			1080		
300			1200		

DATA ANALYSIS and EVALUATION

- a) Enter the results of the experiments you carried out in the table below and then fill in the results for parts of the experiment carried out by other groups:

Time (s)	Loss in mass (g)					
	A	B	C	D	E	F
30						
60						
90						
120						
150						
180						
210						
240						
270						
300						
360						
420						
480						
540						
600						
720						
840						
960						
1080						
1200						

Plot graphs of loss in mass against time for all the parts of the practical on graph paper and use coloured pens as desired.

- b) On each graph, as well as drawing a smooth curve, draw the best straight line through the early points and use this to calculate the initial rate of each part. Record these in the table below:

Part	Initial rate (g s^{-1})
A	
B	
C	
D	
E	
F	

- c) What is the role of part A? Compare your results for part A with those obtained by others and comment on the reproducibility of the experiment. Suggest ways in which this could have been improved.

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- d) What gas was evolved to cause the loss in mass? Bearing this in mind, calculate the initial rate in units of Part A in mole s^{-1} .

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- e) Which reagent was the limiting reagent? Does this correspond to your observations? Taking this into account, how did the actual loss in mass compare with the theoretical? In which parts, if any, would you expect the total mass loss to vary from the value you have calculated?

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- f) What possible factors that could affect the reaction rate have not been investigated as part of this practical?

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- g) For each of the Parts B to F, compare the initial rate with that of Part A and explain this in terms of collision theory.

Part B

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Part C

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Part D

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Part E

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Part F

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Date _____ **Name** _____

Investigation 24

AN INTRODUCTION TO EQUILIBRIUM

This practical is designed as an introduction to the special properties of a system in equilibrium.

ASSESSMENT

This practical will be assessed for *Data Collection* on the accuracy of the observations that you make and for *Data Processing and Presentation* your interpretation of them.

Data Collection	<ul style="list-style-type: none"> Collecting and recording appropriate raw data Presenting raw data allowing easy interpretation 		
Data Processing & Presentation	<ul style="list-style-type: none"> Processing raw data correctly Presenting processed data appropriately 		

METHOD, DATA COLLECTION and ANALYSIS

In this experiment it is important that one section is completed before going on to the next section and for this reason it may be that your teacher chooses to demonstrate the reactions.

The equilibrium involves the formation of a blood-red coloured complex ion from the reaction between iron (III) ions (Fe^{3+} - from iron (III) nitrate) and thiocyanate ions (SCN^- - from potassium thiocyanate).

A The reaction between iron (III) ions and thiocyanate ions

- 1) In a 100 cm³ measuring cylinder mix together 90 cm³ of 0.02 mol dm⁻³ aqueous potassium thiocyanate and 10 cm³ aqueous 0.01 mol dm⁻³ iron (III) nitrate.
- 2) Mix thoroughly and divide the solution equally amongst four 100 cm³ beakers labelled 1, 2, 3, and 4.
- 3) Keep the beaker labelled 1 as a control for the other parts of the experiment. You will use the other three for the later parts of the experiment.
- 4) Record your observations about what you saw taking place as the solutions were mixed and what you can infer from this.

[illegible]

B Increasing the concentration of iron (III) ions

To beaker 2 add 2 cm³ of the aqueous iron (III) nitrate. Compare it with beaker 1.

5) What is the difference?

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6) How can you explain this?

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7) What would you expect the effect of adding extra potassium thiocyanate to be?

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C Increasing the concentration of thiocyanate ions

To beaker 3 add a little solid potassium thiocyanate. Compare it with beaker 1.

8) Were your observations in keeping with your predictions above?

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9) How has adding extra thiocyanate affected the amount of the complex ion?

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10) How can this be explained?

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D Adding fluoride ions

Add a spatula full of solid sodium fluoride to beaker 4. Compare it with beaker 1.

11) How did the colour of the solution change?

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12) How has the concentration of the complex ion been affected?

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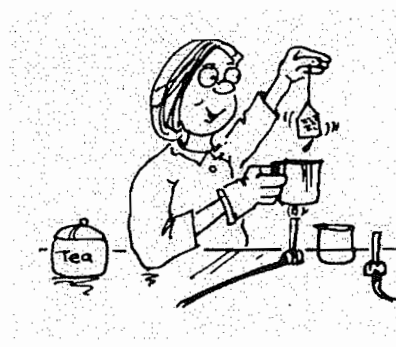
13) Fluoride ions do not react directly with the complex ions but they do react with iron(III) ions to give a colourless, soluble product. What does the effect of fluoride ions show about the reaction of iron(III) ions and thiocyanate ions to form the complex?

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Investigation 25**PREDICTING THE EFFECT OF CHANGES ON AN EQUILIBRIUM**

This is an exercise in planning and demonstrating an understanding of the factors governing the position of an equilibrium.

ASSESSMENT

This practical will be assessed for *Planning (a)* on the way in which you identify the problem you are to study and the relevant variables. It will also be assessed for *Planning (b)* on the practicability of the method you suggest.

Planning (a)	• Defining a problem or research question		
	• Relating the hypotheses or prediction to the research question		
	• Selecting relevant variables		
Planning (b)	• Designing a method with appropriate apparatus/materials		
	• Designing a method for the control of the variables		
	• Designing a method for the collection of sufficient data		

Identification of RESEARCH PROBLEM

1. You will first need to identify a suitable equilibrium system to study - one in aqueous solution will probably prove simplest. Those involving weak acids and bases, sparingly soluble salts, the formation of complex ions by metals are all possibilities. The most important thing is to be able to easily make a qualitative assessment of the position of the equilibrium in the system.

System to be studied

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2. You will then need to consider the variable that you wish to manipulate, the one you wish to observe and the other variables that will need to be controlled.

3.

Manipulated (Independent) variable

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Observed (Dependent) variable

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Controlled variables

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4. Finally you should use your knowledge of such systems to hypothesise the way in which you would expect the change in the conditions you intend to make to affect the equilibrium position and hence the observable characteristics.

Hypothesis:

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METHOD

You are expected to write your own method below giving full practical details of amounts, concentrations, times, apparatus to be used etc. Provide and attach your own paper please.

Some of the questions that you will have to ask yourself are:

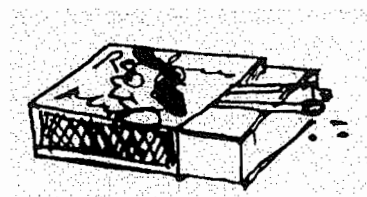
1. Will the system be in equilibrium under the suggested conditions?
2. How am I going to monitor the characteristic that indicates the position of equilibrium?
3. What precautions are necessary to ensure that only one variable is being changed?
4. Will the change made be sufficient to produce an observable effect?

DATA COLLECTION and ANALYSIS

What did you observe when you carried out your practical? What did this indicate?
(Use extra line or graph paper if required)

EVALUATION

How successful was your experiment? What were the problems? How could/did you modify it to overcome these?



Investigation 26

A COMPARISON OF STRONG AND WEAK ACIDS AND BASES

Acids have a number of reactions in common. This practical studies these and also compares the behaviour of strong and weak acids and bases.

ASSESSMENT

The practical will be assessed for *Data Collection* on the accuracy of your observations and *Data Processing and Presentation* on your explanation of these results.

Data Collection	<ul style="list-style-type: none"> Collecting and recording appropriate raw data Presenting raw data allowing easy interpretation 		
Data Processing & Presentation	<ul style="list-style-type: none"> Processing raw data correctly Presenting processed data appropriately 		

Warning Please take care, some of these chemicals and techniques are hazardous



METHOD

- 1) Use narrow range pH paper to measure the pH of 0.01 M hydrochloric acid. Repeat this using 0.1 M hydrochloric acid, 1 M hydrochloric acid and 1 M ethanoic acid.
- 2) Put some distilled water into the conductivity apparatus and take the reading. Now repeat this with 0.01 M hydrochloric acid, then 0.1 M hydrochloric acid, 1 M ethanoic acid and finally 1 M hydrochloric acid, being careful to rinse the apparatus with the next acid before filling it and taking the reading.
- 3) Repeat 1) and 2) using aqueous sodium hydroxide instead of hydrochloric acid and 1 M aqueous ammonia instead of ethanoic acid.
- 4) Put a 2 cm depth of 1 M hydrochloric acid into a test tube and then add a small marble chip. Repeat using 1 M sulfuric acid, 1 M nitric acid, 1 M ethanoic acid, 0.1 M hydrochloric acid and 0.01 M hydrochloric acid. Compare the rates of reaction.
- 5) Put a 2 cm depth of 1 M hydrochloric acid into a test tube and then add a 1 cm piece of magnesium ribbon. Repeat using 1 M sulfuric acid, 1 M nitric acid and 1 M ethanoic acid.
- 6) Put a 2 cm depth of 1 M hydrochloric acid into a boiling tube and add a **small** amount (just enough to see) of copper oxide. Warm the boiling tube gently until there is no further change. Repeat using 1 M sulfuric acid, 1 M nitric acid and 1 M ethanoic acid.
- 7) Use a measuring cylinder to put 10 cm³ of 1 M hydrochloric acid into a small conical flask. Add a few drops of phenolphthalein indicator to this. Add 1 M aqueous sodium hydroxide from a burette, recording how much is required to produce a permanent pink colour. Repeat using 1 M sulfuric acid, 1 M nitric acid, 1 M ethanoic acid, 0.1 M hydrochloric acid and 0.01 M hydrochloric acid.

DATA COLLECTION

Record the results of your practical in a suitable form on extra pages as required.

DATA ANALYSIS

a) How did the pH value of the hydrochloric acid vary with concentration?

Was this what you would have expected? Why?

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b) How did the ethanoic acid compare? Can you use these data to estimate what percentage of the ethanoic acid is ionised?

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c) Explain why the conductivity of the hydrochloric acid varied with concentration.

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d) What does the value for ethanoic acid show about the acid?

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e) In a similar way, explain the differences in pH and conductivity that you observe with the various solutions of sodium hydroxide and ammonia

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f) Can you explain the order of reactivity that you found for the reaction of the various acids with the marble chips?

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g) Write an ionic equation for the reaction of an acid with a marble chip.

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h) The sulfuric acid may have reacted in an unexpected manner with the marble chip.
What caused this behaviour?

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i) Was the order of reactivity of the acids with the magnesium ribbon similar to that with the marble chip?

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j) Write an ionic equation for the reaction of magnesium ribbon with an acid.

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k) How did the rate observed for 1 M ethanoic acid compare with that observed for the other acids of a similar concentration. Explain any differences.

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l) What features did the reactions of the different acids with the copper oxide all have in common?

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m) Write balanced equations for each of the reactions and name the salts formed.

with hydrochloric acid

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with sulfuric acid

.....

with nitric acid

with ethanoic acid

n) Write an ionic equation that could replace all of the equations above.

o) Which three acids required about the same amount of aqueous sodium hydroxide to neutralise them?

p) Why did the sulfuric acid require more alkali than the others. Was the volume required about what you would have expected?

q) Why did the more dilute samples of hydrochloric acid require much smaller volumes of the alkali?

r) Why was the ethanoic acid similar to the other acids of a similar concentration on this occasion?

s) Write an ionic equation for the reaction between an acid and an alkali.

t) All acids undergo certain characteristic reactions. Suggest, from this practical investigation, what some of them might be.

- u) Ethanoic acid is a **weak acid**, whereas hydrochloric, sulfuric and nitric acids are **strong acids**. What does this mean and in which parts of the practical was this difference apparent?

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- v) What is a base? Name three substances that have acted as bases in the reactions carried out in parts 3) to 6) and explain how their behaviour shows they are bases.

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- w) In reaction 3) did the magnesium act as a base? Explain how you reach this conclusion. If this was not an acid-base reaction, what kind of reaction was it?

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Investigation 27

COMMON OXIDANTS AND REDUCTANTS

The object of this experiment is to carry out a number of redox reactions involving common oxidants and reductants. To observe the changes that occur, to interpret these in terms of the reactions occurring and to write balanced equations using the half equation method.

ASSESSMENT

The main focus of this assessment will be for *Data Collection* on the accuracy of your observations and for *Data Processing and Presentation* on your interpretation of these results.

Data	• Collecting and recording appropriate raw data		
Collection	• Presenting raw data allowing easy interpretation		
Data Processing &	• Processing raw data correctly		
Presentation	• Presenting processed data appropriately		

Warning Please take care, some of these chemicals and techniques are hazardous



METHOD

- Put a 2 cm depth of aqueous iron(II) sulphate into two separate test tubes. Add an equal volume of hydrogen peroxide solution to one and then warm it for a minute. Finally add aqueous sodium hydroxide to both test tubes until permanent precipitates form. Leave these to stand until the end of the practical and note any further changes that have occurred.
- Put a 2 cm depth of aqueous copper sulphate in a test tube and add a small piece of granulated zinc.
- Put a 2 cm depth of aqueous potassium iodide in a test tube and add chlorine water a little at a time until there is no further change.
- Put a 2 cm depth of aqueous potassium dichromate(VI) into a test tube and add aqueous sulfur dioxide a little at a time until there is no further colour change.
- Put a small piece of magnesium ribbon into a test tube, add about a 2 cm depth of dilute hydrochloric acid. Put your finger over the end of the test tube and test the gas with a lighted splint.
- Put a 1 cm depth of potassium permanganate(VII) solution into a test tube and add a 2 cm depth of dilute sulfuric acid. Now add a 2 cm depth of aqueous ethanedioic acid (oxalic acid, $\text{H}_2\text{C}_2\text{O}_4$; CARE - POISON!) and warm gently. "Pour" the gas evolved into a second test tube containing a 1 cm depth of limewater and gently shake the limewater.
- Put a 2 cm depth of potassium permanganate(VII) solution into a test tube and add a 1 cm depth of dilute sulfuric acid. Now add a 2 cm depth of hydrogen peroxide. Test the gas evolved with a glowing splint.
- Put a 2 cm depth of water into a test tube and add a spatula full of calcium. Place your thumb over the end of the boiling tube and test the gas with a lighted splint.

DATA COLLECTION and ANALYSIS**For each of the reactions**

- Observation** - accurately record your observations.
- Interpretation** - from these deduce the changes occurring and hence what was being oxidised and what was being reduced.
- Balanced equation** use the half equation method to write a balanced equation for the reaction.

Iron (II) and Hydrogen Peroxide

Observation

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At the end of the session?

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Interpretation

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Oxidised - Reduced

Balanced equation:

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Zinc and copper(II)

Observation

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Interpretation

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Oxidised - Reduced

Balanced equation:

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Chlorine and iodide

Observation

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Interpretation

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Oxidised - Reduced

Balanced equation:

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Dichromate(VI) and sulfur dioxide

Observation

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Interpretation

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Oxidised - Reduced -

Balanced equation:

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Magnesium and hydrochloric acid

Observation

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Interpretation

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Oxidised - Reduced

Balanced equation:

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Permanganate(VII) and ethanedioic acid

Observation

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Interpretation

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Oxidised - Reduced

Balanced equation:

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Permanganate(VII) and hydrogen peroxide

Observation

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Interpretation

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Oxidised - Reduced

Balanced equation:

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Calcium and water

Observation

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Interpretation

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Oxidised - Reduced

Balanced equation:

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Investigation 28

SOME REACTIONS OF HYDROCARBONS

This practical is designed to compare and contrast the behaviour of different classes of hydrocarbons.

ASSESSMENT

In this practical you will be assessed for *Planning (a)* on your suggestions for testing the unknown organic substances, *Data Collection* on the accuracy of your observations and *Data Processing and Presentation* on your interpretation of these.

Planning (a)	• Defining a problem or research question		
	• Relating the hypotheses or prediction to the research question		
	• Selecting relevant variables		
Data Collection	• Collecting and recording appropriate raw data		
	• Presenting raw data allowing easy interpretation		
Data Processing & Presentation	• Processing raw data correctly		
	• Presenting processed data appropriately		

Warning Please take care, some of these chemicals and techniques are hazardous



METHOD and DATA COLLECTION

- Put a few drops of cyclohexane on a watch glass or evaporating basin. **Make sure that the bottle is well away**, then, preferably after transferring it to a fume cupboard, ignite the liquid. Note the flammability and observe the nature of the flame produced. Repeat this using firstly cyclohexene and then methylbenzene (toluene) instead of cyclohexane, comparing the different hydrocarbons with each other. Record your observations below.
Cyclohexane

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Cyclohexene

.....

Methylbenzene

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- 2) Put a 1 cm depth of bromine water into two separate test tubes and add a few drops of cyclohexane to each. Loosely stopper the tubes, shake them and observe what occurs. Repeat this with a second pair of test tubes, but this time adding cyclohexene rather than cyclohexane. Now place one of each pair of test tubes in a dark cupboard and the other in bright sunlight, then leave for about ten minutes. At the end of this time observe again and test the gas in the test tube with a piece of filter paper dipped in aqueous ammonia.

Cyclohexane

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Cyclohexene

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- 3) Put a 1 cm depth of acidified potassium permanganate into a test tube and add a few drops of the hydrocarbon. Shake and record your observations carefully.

Cyclohexane

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Cyclohexene

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- 4) If you were provided with an unknown organic compound and these reagents, what could you determine about it?

Research question

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Hypothesis:

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Write down any assumptions made:

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This image shows a full page of a handwriting practice worksheet. It consists of multiple horizontal rows, each defined by two parallel dotted lines. The rows are evenly spaced and extend across the entire width of the page, providing a guide for letter height and placement. There is no text or other markings on the page.

a) Calculate the number of hydrogen atoms per carbon atom in the three known hydrocarbons used. Does this correlate with changes in the nature of the flame in the first part of the practical?

[illegible]

b) Write a balanced equation for the complete combustion of methylbenzene.

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c) Did this seem to occur? What was your evidence?

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- d) In what way would the products of combustion differ from those of complete combustion?
Write a balanced equation for the reaction that gives these products from methylbenzene.
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- e) For what reasons might complete combustion of a fuel be preferable to incomplete combustion?
.....
.....
- f) How would you try and modify the way in which methylbenzene was burnt if you wished to achieve complete combustion?
.....
.....
.....
- g) Write a balanced equation for the reaction of bromine water with cyclohexene. To what class of reactions does this belong?
.....
.....
- h) Explain the immediate changes that you observed when bromine water was added to cyclohexane.
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.....
- i) Why did cyclohexane react with bromine water in the presence of sunlight, but not in the dark?
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.....
- j) Explain your observations when the gas over the liquid was tested with filter paper dipped in ammonia.
.....
.....
- k) Write a balanced equation for the reaction of cyclohexane with bromine in the presence of sunlight. What class of reactions does this belong to?
.....

- l) What other products might occur in small traces with cyclohexane? If this compound were left in the presence of light and a large excess of bromine for some time, what would be the eventual product?

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- m) Explain why you might have predicted the reactions of cyclohexane and cyclohexene with acidified potassium permanganate. To what class of reactions do you think the reaction between acidified permanganate and cyclohexene belongs?

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- n) Explain the distribution of the colour between the aqueous and non-aqueous layers when aqueous permanganate is mixed with cyclohexane.

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- o) What conclusions could you come to about the nature of the unknown organic substances?

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Investigation 29

INVESTIGATING ORGANIC STRUCTURES USING MODELS

In this practical you will investigate the three dimensional nature of organic molecules and some of the consequences of this.

ASSESSMENT

This practical will be assessed for *Data Processing and Presentation* on the way in which you use the models you make, to answer the questions posed and *Manipulative Skills* on the skill and accuracy with which you construct the models.

Data Processing & Presentation	• Processing raw data correctly		
	• Presenting processed data appropriately		
Manipulative Skills	• Using techniques and equipment in a safe manner		
	• Following instructions accurately and thoughtfully		

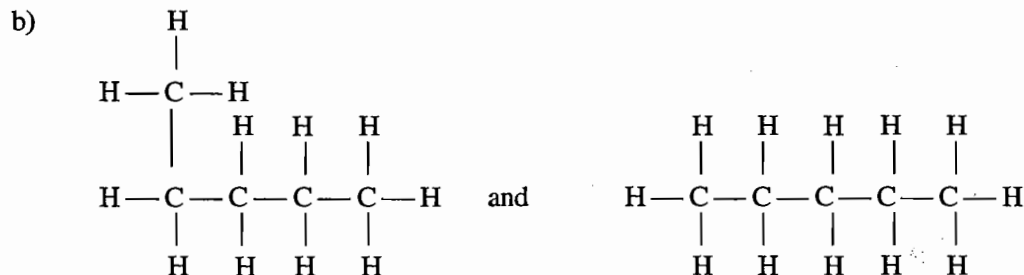
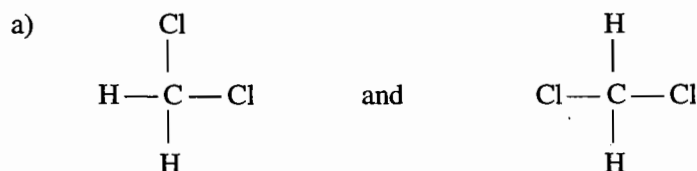
METHOD

In building these structures, as in all organic compounds, carbon atoms (often black) must have 4 bonds, nitrogen (often blue) 3 bonds (unless it is part of an NO₂ group), oxygen (often red) 2 bonds, hydrogen (often white) and halogen atoms (often green) 1 bond. The structures can of course contain double and triple bonds.

2 or 3 dimensions?

We draw organic structure in two dimensions, when in practice they are of course three dimensional. This can sometimes lead to confusions!

Build models of the following pairs. Are they the different, as they appear on the drawings? If not, why not?



Explanation?

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Structural isomers

Isomers are compounds that have different structures, but the same molecular formula. Isomers have different physical properties, because of their different shapes, polarities etc. and they may have different chemical properties if they contain different functional groups.

Try building as many different structures as you can with the formula $C_4H_{10}O$. Draw diagrams of each structure and number these. Try to group together the different structures that you produce and describe the way in which the structures of the different isomers are related.

Drawings of structures:

Total number of isomers? _____

Proposed groupings?

.....
.....

Explanation of the relationship?

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.....
.....
.....

Geometrical (cis-trans) isomers

Make a model of 1,2-dichloroethane and 1,2-dichloroethene. Are two structures possible in either case? If they are, draw these and explain why they are possible. One of your structures is called the cis- isomer, the other the trans- isomer. Find out which is which and label them.

Can you make other isomers (not necessarily 1,2-) of these compounds? Draw these structures:

Are there cis- and trans- isomers of these? Explain why or why not.

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Consider all of the structures that you have drawn. Which would you expect to be polar molecules and which non-polar?

Polar:

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Non-polar:

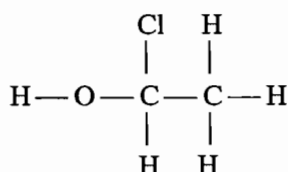
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A similar type of isomerism exists in molecules that contain a ring of carbon atoms. Considering this, how many possible isomers are there of $(\text{CHCl})_6$ 1.2.3.4.5.6-hexachlorocyclohexane?

Enantiomers (Optical Isomers)

It is possible to make two model of the molecule below that are not exactly identical.



Make models of these and describe how they are related. Try and draw diagrams that give a 3-dimensional feel about the differences between them.

If you replaced the -OH by another H, would you still be able to make two different models? Explain the conditions required for two different structures to exist.

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The molecules represented by these models are very similar and only have a very minor difference in their physical properties. Find out what this difference is and write it down, being very careful to express it precisely.

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Find out what is meant by the following terms that relate to this kind of isomerism:

Asymmetric carbon atom

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Optically active

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Racemic mixture

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This last concept provides a way in which a product extracted from a natural source can often be distinguished from one that is prepared synthetically. Explain how.

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Investigation 30**THE PREPARATION OF A LIQUID ALKENE**

This practical is an introduction to synthetic organic chemistry. The object is to produce the desired organic compound by a suitable reaction and then to isolate this product from excess reactants, the other products and the products of side reactions. Ideally this should result in a high yield of the pure compound.

ASSESSMENT

This practical will be assessed for *Conclusion and Evaluation* on your assessment of the technique including ways to improve it and *Manipulative Skills* on the yield and quality of your product, coupled with the skill that you show in handling the apparatus.

Conclusion and Evaluation	• Stating a valid conclusion based on interpretation of results		
	• Evaluating the procedure including limitations and errors		
	• Suggesting a modified procedure to improve the investigation		
Manipulative Skills	• Using techniques and equipment in a safe manner		
	• Following instructions accurately and thoughtfully		

Warning Please take care, some of these chemicals and techniques are hazardous

**METHOD**

- 1) Measure 12 cm³ of water into a small beaker and add to this, a little at a time and with constant stirring, 6 cm³ of concentrated sulfuric acid (Care!). Cool the diluted acid to room temperature and transfer to a 50 cm³ Quickfit flask.
- 2) Measure out 12 cm³ of 2-methylbutan-2-ol (tertiary amyl alcohol) and add this to the flask a little at a time, swirling the contents between additions.
- 3) Set up the Quickfit apparatus for distillation with a thermometer, using a test tube cooled in iced water as the receiver.
- 4) Heat the flask with a beaker of very hot water (*Caution - no naked flames near the apparatus as the vapour is highly flammable*) until no more product distils over. Record the temperature at which the product distils. You may need to periodically renew the hot water.
- 5) Transfer the product to a 10 cm³ measuring cylinder and record the yield of crude product.
- 6) Add one drop of your product to a little bromine water in a test tube.
- 7) If time allows, the crude product may be further purified by
 - i) Shaking with 2 cm³ of aqueous sodium hydroxide.
 - ii) Separating the product from the alkali, using a separating funnel.
 - iii) Adding a few granules of anhydrous calcium chloride and leaving for an hour or two.
 - iv) Redistilling the product using clean, dry, Quickfit apparatus.

DATA COLLECTION

	Crude product	Purified product
Boiling point	= _____ °C	= _____ °C
Volume	= _____ cm ³	= _____ cm ³

DATA ANALYSIS

a) Calculate the percentage yield of the crude product, based on the amount of alcohol taken.

[Densities: 2-methylbutan-2-ol = 0.806 g cm⁻³; product = 0.662 g cm⁻³]

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b) Suggest two possible structures for the alkene produced. In what ways might you attempt to discover which is formed, or the composition of the mixture if this is the result.

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c) What would you expect as the major impurities in your crude product?

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d) Explain the role of the following in the final purification of the product:

i) Aqueous sodium hydroxide.

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ii) Anhydrous calcium chloride.

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iii) Redistillation.

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e) What did the test with bromine water show?

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f) Was there any indication of the purity of your product? How could this be further investigated?

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g) Do you think you obtained a reasonable yield or did specific occurrences limit this?

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h) Assuming that your yield was less than 100%, what do you consider were the probable reasons for this?

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i) In what way(s) do you think that the yield of pure product could have been increased?

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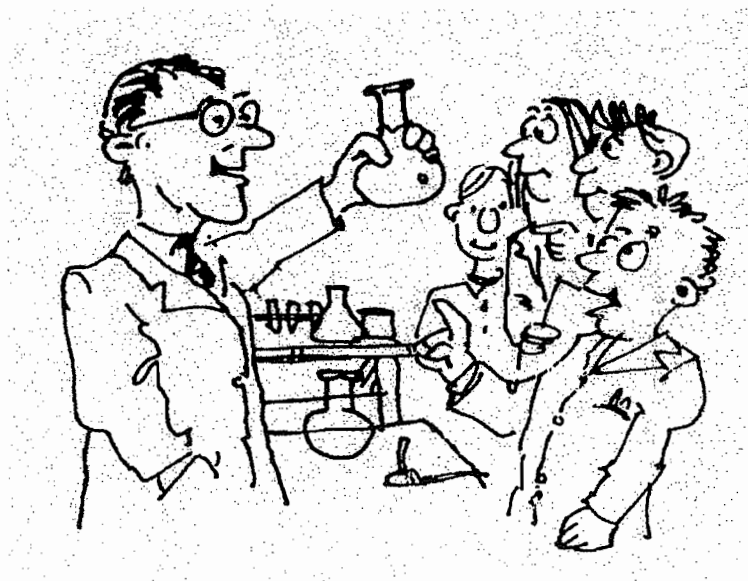
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A PORTFOLIO OF INVESTIGATIONS IN CHEMISTRY

(for use with the IB Diploma programme)

(relevant to SSC)

Teaching Notes



Author: Dr John Green
Series editor: David Greig

INTERNAL ASSESSMENT PROCEDURES

The following information has been prepared by the Editor of this series, in conjunction with the authors of the various Portfolios in this series. We would like to acknowledge the assistance and advice given by a Curriculum and Publications officers of IBO and the following extracts are published with their permission. The other information is not IBO policy but is our interpretation only which we offer to you in good faith. However we realise that interpretations and procedures vary and will change as the courses develop and we can take no responsibility whatsoever for any consequences arising from the use of this interpretation. If in doubt please consult the relevant IBO Internal Assessment documents or seek advice from IBO.

Information for teachers

The process of skill assessment can be onerous. To make your work as simple and easy as possible, we have devised an Assessment Table which shows the 8 *skills* together with the relevant *criteria* and also includes a space for you to record whether students have demonstrated these 'completely', 'partially' or 'not at all'. There is also provision for you to record the Level awarded for each skill, in each investigation. An 'Assessment table' is included in the Student Portfolio together with some advice for students. We have also taken sections of the table and included them within each Investigation so that the students are aware of exactly what will be assessed. Of course this is advice only and in no way prescriptive. Teachers may wish to use the Investigations to assess other skills or may wish to keep a record of progress in other ways.

Teaching Notes

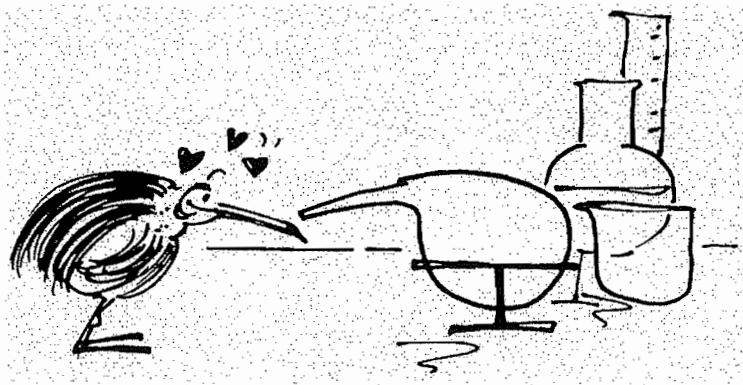
On the following pages there are a collection of notes for the information of Heads of Department, Teachers and/or Laboratory Managers that will help in getting each practical to run smoothly. We realize that Health and Safety regulations vary from country to country and we strongly suggest that local regulations be checked and observed at all times. Although these Investigations and Teaching Notes have been prepared in good faith, *absolutely no responsibility whatsoever* will be accepted by the writer, editor or publisher for the safe and legal conduct of these activities.

They have been prepared in such a way that a teacher can photocopy them and complete the top section as an easy way to order materials as required.

Some additional notes from the Author

Many of these practicals were written before the recent IB "clarification" of the skills and the interpretation of Data Analysis for a number of practicals is perhaps rather broader than the current IB interpretation. In Data Analysis I also include the skill of being able to interpret the results obtained in terms of relevant theory. This skill seems to be almost totally lacking in the current IB interpretation, unless it is the first criterion of the Evaluation skill. Unfortunately many of the practicals involved are test tube reactions, totally unsuited to the other two criteria, so not really appropriate for assessing Evaluation. I have therefore left them as Data Analysis, but you may prefer to omit them, at least for the purposes of the final IB mark.

With uncertainties, my personal approach is to cover the formal part early on in the course, using gravimetric analysis, so that the students have the skills if they are required. I then do not address the issue of the formal assessment of uncertainties in the other quantitative sections because the random errors tend to far outweigh the systematic ones, hence I tend to regard it as rather a waste of time. If you prefer your students to always record uncertainties in measurement and hence the uncertainty of the final result, then please instruct them accordingly - I think the Data Collection sections will still prove adequate."



Investigation 1 THE SEPARATION OF MIXTURES - A revision exercise

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required

As with all student planned practicals it is difficult to be precise as to the apparatus required, but the following is probable:

- Weighing bottles
- Test tubes
- Beakers (various sizes)
- Conical flasks (various sizes)
- Filter funnels
- Filter paper
- Evaporating basin
- Centrifuge (if available)

Chemicals required

A range of cheap, readily available soluble and insoluble solids. Personally I would limit the students to water as a solvent, but if you feel more adventurous you will also require supplies of the solvents you are happy for them to use.

Notes

Probable timing - 45 minutes planning, 75 minutes laboratory time

This is fairly simple preliminary exercise. It should be useful for students who have little experience of practical chemistry, or as an introduction to planning for those students who have experience of laboratory work, but little familiarity with planning it.

The amount of guidance you give with the planning is of course up to you and will vary considerably from group to group. Similarly the variety of substances you make available to the students will dictate the degree of difficulty. Most would have some idea of how they would expect to separate salt and sand, but many might be less certain about magnesium carbonate and nickel sulphate for example. You may wish to have just one mixture, or you can make a variety of soluble and insoluble substances available, yielding a much wider range of possible mixtures.

It is easy to make this a little more challenging by having a few hydrated salts, or things that decompose easily when heated. There is also the possibility of extending the exercise to use non-aqueous solvents, though this may also increase the hazards as many are flammable and recovery of the soluble component will probably entail the use of distillation apparatus. You may also wish to introduce a centrifuge, or suction filtration as possible separation methods. I would normally spend some time in one lesson introducing the practical and set the planning for a homework exercise. I would then collect it in, mark and correct it (especially looking at safety considerations) and then return it to the students the day before they carry out the investigation, so that they have time to read through the changes.

With most mixtures, yields of both components should be good, watch out though for >100% of the insoluble component owing to failure to wash the solid to remove the soluble component. Salt hydrates and substances prone to thermal decomposition can also lead to "interesting" yields.

Investigation 2 PREPARING A SOLUBLE SALT FROM AN INSOLUBLE SOLID

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required

This will vary according to students' plans, but probably a selection of

Burettes & burette funnels	Pipettes & pipette fillers
Volumetric flasks	Measuring cylinders
Weighing bottles	Conical flasks
Beakers	Filter funnels and paper
Evaporating basins	Top pan balance reading to 0.01 g
Centrifuge?	

Chemicals required

This will depend on what is available and what the students request. It would be useful to list the materials available so the students can select from these.

Appropriate materials would be:

The metal, its oxide and its carbonate for any of the following:

Magnesium, aluminium, iron, zinc, nickel, cobalt, copper etc.
(silver and lead are best avoided).
Stock (5 M?) solutions of appropriate acids, such as
hydrochloric, nitric, sulfuric, ethanoic, citric etc.

Notes

Probable timing - 45 minutes planning, 75 minutes laboratory time

This is another preliminary exercise that is useful to introduce students to practical work and also to introduce the planning of practicals. I also like this because many students have had no experience of preparative chemistry and find that producing something at the end is very satisfying.

The amount of guidance you give with the planning is of course up to you and will vary considerably from group to group. Similarly the substances you make available to the students will to some extent affect the degree of difficulty. It may be advisable to decide whether you want them to produce crystals (evaporate to a concentrated solution then leave to cool), or whether you want them to produce a powdered product (evaporating to dryness). You can do either on a water bath or over a Bunsen according to the thermal stability of the probable products.

Personally I like to use copper, nickel, cobalt etc. because students find coloured products particularly attractive. There is also of course a slight toxic hazard with metals such as these. Some care is also needed with these and others that produce hydrated salts, and perhaps nitrates are best avoided with all but the best students owing to the problems of their fairly high solubility and ease of thermal decomposition.

I would normally spend some time one lesson introducing the practical and set the planning for a homework exercise. I would then collect it in, mark and correct it (especially looking at safety considerations) and then return it to the students the day before they carry out the investigation, so that they have time to read through the changes.

Investigation 3 THE PREPARATION AND PROPERTIES OF SOME COMMON GASES

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

Boiling tube	2 x Test tube
~3 wooden splints	

Chemicals required

About 20 g of each of the following: **About 20 cm³ of each of the following:**

Magnesium ribbon	Dilute hydrochloric acid
Manganese (IV) oxide (MnO ₂)	Dilute nitric acid
Marble chips	Limewater
	1 mol dm ⁻³ aqueous hydrogen peroxide
	Dilute sulfuric acid

A few pieces of:

Red litmus paper
Blue litmus paper

Generally available: Cylinder of carbon dioxide

For the demonstration:

500 cm ³ conical flask	“100-volume” hydrogen peroxide
liquid detergent	~5 g “red lead” (Pb ₃ O ₄ powder)

Notes

Probable timing - 60 minutes laboratory time

If you have a group of students who have hardly ever been exposed to practical chemistry before, then this can be a very good starting point as it is relatively simple and it introduces them to some very important gases. The effects of excess carbon dioxide and the reactions of marble chips with other acids does extend it slightly and a few students will have to think, or research, a bit to come up with appropriate examples.

Demonstration

WARNING - this involves 100-Volume hydrogen peroxide, which is a very corrosive liquid, blistering the skin easily. Keep the students well back, do not allow them to touch the foam and wear gloves on your hands, especially when cleaning up. Note too that “red lead” (Pb₃O₄), like all lead compounds is quite toxic.



This is an excellent opportunity for a “fun” demonstration based on the catalytic decomposition of hydrogen peroxide. Put a couple of spatulas full of “red lead” into the bottom of a 500 cm³ conical flask and add a good squirt of detergent and about an equal volume of water, then swirl it around the inside of the flask. Support the flask on a tripod over a sink (for easy cleaning up!), tip in about 25 cm³ of the 100-Volume hydrogen peroxide and stand back. You should get a pink foam serpent erupting out of the top of the flask. It does work with manganese(IV) oxide, but I prefer the pretty pink produced by the “red lead”.

Investigation 4 PURIFYING A SUBSTANCE BY RECRYSTALLISATION

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

2 x 100/150 cm³ conical flasks

Filter funnel

Spatula

Suction filtration apparatus - pump, Buchner flask and funnel

Vial and stopper

Wash bottle of distilled water

also generally available

Top pan balance reading to 0.01 g

Filter paper for both normal and Buchner funnels

Chemicals required

Mixture for purification (- 3 g per student)

100:10:1 approx. benzoic acid : charcoal : methylene blue

Notes

Probable timing - 90 minutes laboratory time

This provides a good chance to assess the manipulative skills of your students, as well as providing a chance to introduce techniques such as suction filtration. The colour of the eventual product gives you a good indication as to how successful they have been at eliminating the impurities, charcoal making the product grey and methylene blue imparting a blue colour. Yields are generally quite good, but can vary considerably. As is usually the case a good yield is not infrequently at the expense of rather high impurity levels. One of the real secrets is allowing the crystals to form slowly, but students are rarely patient enough for this!

Investigation 5 TESTS FOR ANIONS AND CATIONS

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

3/4 test tubes
100 cm³ beaker
Stirring rod

Chemicals required

About 100 cm³ of each of the following, per group:

Dilute nitric acid
Aqueous silver nitrate (0.1M)
Aqueous barium chloride or nitrate (0.1M)
Aqueous sodium hydroxide (1M)
Limewater

About 100 cm³ of approximately 1M (except where shown) aqueous solutions of the following to share, labelled as shown:

“Carbonate” - Sodium carbonate
“Chloride” - Sodium chloride
“Sulphate” - Sodium sulphate
“Magnesium” - Magnesium sulphate
“Aluminium” - Aluminium sulphate
“Iron(II)” - Iron(II) sulphate
“Iron(III)” - Iron(III) chloride
“Copper” - Copper sulphate
“Silver” - Silver nitrate (0.1 M)

About 20g of each of the following solids labelled with the letter shown

A Magnesium carbonate
B Magnesium chloride
C Magnesium sulphate
D Aluminium chloride
E Aluminium sulphate
F Iron(II) carbonate
G Iron(II) chloride
H Iron(II) sulphate
I Iron(III) chloride
J Iron(III) sulphate
K Copper carbonate
L Copper chloride
M Copper sulphate
N Silver carbonate

Notes

Probable timing - 120 minutes laboratory time (60 for each part)

A very simple qualitative analysis exercise, but I have included it because it is amazing in these days of General Science courses, how many students arrive at their last two years of schooling without knowing how to test for a chloride, or for an iron salt. Students always seem to enjoy the detective work in Part B!

Investigation 6 WATER OF CRYSTALLISATION

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

Bunsen burner
Tripod
Pipeclay triangle
Crucible with lid

also generally available

Balance capable of weighing to at least 0.01 g

Chemicals required

About 10 g per group of one or more of the following solids:

Hydrated magnesium sulphate crystals
Hydrated copper(II) sulphate crystals
Hydrated barium chloride crystals
Hydrated nickel sulphate crystals

Notes

Probable timing - 60 minutes laboratory time

This is a straightforward quantitative gravimetric exercise and should give good results. If you use hydrated barium chloride, do not forget to warn the students how toxic it is.



I usually use a variety of salts and label them A, B, C etc.

I also use this practical to introduce students to the idea that there is a finite precision to quantitative work, as a result of random and systematic errors. It is up to you whether you wish to carry out a full treatment of how to handle the precision of measurements, or whether you just wish them to work out the maximum error that the weighings could have produced and the effect this would have on the final result. I also, perhaps more importantly, get students to work through whether a particular possible error, such as spilling a little of the solid, would lead to a higher or lower value for the final result.

Investigation 7 COMPOSITION OF COPPER CARBONATE

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

Bunsen burner

Tripod

Pipeclay triangle

Crucible with lid

also generally available

Balance capable of weighing to at least 0.01 g

Chemicals required

Copper carbonate (~10 g per student)

Notes

Probable timing - 60 minutes laboratory time

This is very closely related to the previous practical. Because of the greater complication in working out the required results I tend to prefer this with a more able group of students - with very good students you could even omit the guidelines as to how to calculate the result. If you were to do both, this one could be perhaps adapted as a planning exercise. "Copper carbonate" varies quite a lot between suppliers, so you really need to do your own determination to find out the "right" answer (or average out the results of your 2 or 3 most reliable students!).



Investigation 8 HOW CONCENTRATED IS 'CONCENTRATED' NITRIC ACID?

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

Burette
Burette funnel
25 cm³ pipette
10 cm³ pipette
Pipette filler
100 cm³ volumetric flask
250 cm³ Volumetric flask
Weighing bottle
2 x 100/150 cm³ conical flask

also generally available:

Top pan balance reading to 0.01 g

Chemicals required

Concentrated nitric acid (~10 cm³ per group)
Solid anhydrous sodium carbonate (~10 g per group)
[should be dried in an oven at ~110°C for 24 hours]

Notes

Probable timing - 90 minutes laboratory time

This is my introduction to volumetric analysis. I have not specified a particular method and I find that many teachers have their own particular preferences when it comes to making up standard solutions etc. Besides which I prefer to demonstrate the "correct" (in my eyes!) use of the apparatus and explain the reasons why I like things done in a certain way. Having the students write up the Method, should reinforce this information. As it is an initial exercise, I lead the students very much step by step through the analysis. At the end of the Analysis and Evaluation are a couple of related calculations which should test the brighter students.

Investigation 9 THE SOLUBILITY OF ETHANEDIOIC ACID

Day/Date of lesson _____ Period _____ Room _____
Teacher _____ No. of students/groups _____

As with all student planned practicals, it is not possible to precisely predict the apparatus required, but the following are likely to be requested.

Apparatus required

- Burette and burette funnel
- Pipettes of various sizes and pipette fillers
- Volumetric flasks of various sizes
- Weighing bottles
- Conical flasks
- Beakers
- Filter funnels and filter papers
- Top pan balance reading to 0.01 g

Chemicals required

Ethanedioic acid dihydrate (~10 g per group)

N.B. Students are also likely to request solutions of aqueous sodium hydroxide and aqueous potassium permanganate. As the concentrations requested may vary, it will most likely be simplest to have quite concentrated solutions available that students can then dilute as required. Students are also likely to request various acid-base indicators.

Notes

Probable timing - 90 minutes planning, 60 minutes laboratory time

This is an exercise that I usually use quite near to the end of the two year course. By this time, students should be able to come up with a couple of possible methods, evaluate the potential accuracy of both and write a practicable procedure for the preferred method. There are plenty of options, both gravimetric and volumetric so they should not find it too difficult to think of two possibilities. I would usually give them a short briefing and set them a homework session to consider possible ways that they could determine the solubility. I would then give them one lesson to produce the planning and a second lesson, after I had evaluated their plans, especially with regard to safety, in which they could carry out their determination.

Please be sure to point out to students the toxic nature of ethanedioic (oxalic) acid.



Investigation 10 DETERMINING THE MOLAR MASS OF A SOLUBLE ACID

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

As the students plan their own practical, the precise apparatus and amounts of reagents they will decide to use is difficult to predict. The list below gives the type of apparatus and quantities of reagents that students are likely to require

Apparatus required

- Burette
- Burette funnel
- Various pipettes
- Pipette filler
- Various volumetric flasks
- Weighing bottles
- Various beakers
- Various conical flasks
- Top pan balance reading to at least 0.01 g

Chemicals required:

- Aqueous sodium hydroxide, approximately 0.1 mol dm^{-3} (~300 cm³ each)
- Solid potassium hydrogenphthalate (~2 g per student)
- Solid citric acid (~2 g per student) labelled as "Acid X"
- Phenolphthalein indicator

Notes

Probable timing - 60 minutes planning, 60 minutes laboratory time

I use this as a fairly straightforward planning exercise at the end of my volumetric analysis section. As usual with planning, I get the students to write out their plan in one lesson, then collect these in to check them for practicability and safety before allowing them to carry it out in a later lesson.

Investigation 11 DETERMINING THE NITROGEN CONTENT OF A FERTILISER

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

Burette
Burette funnel
25 cm³ pipette
10 cm³ pipette
Pipette filler
Weighing bottle
250 cm³ conical flask
100/150 cm³ conical flask
Wash bottle of distilled water

also generally available

Top pan balance reading to at least 0.01 g

Chemicals required

Standardised 1 mol dm⁻³ hydrochloric acid (~300 cm³ per student)
Approximately 2 mol dm⁻³ aqueous sodium hydroxide (~200 cm³ per student)
Solid ammonium sulphate, labelled "Fertiliser" (~2 g per student)
Bromothymol blue indicator (2/3 cm³ per student - can share a bottle)
Red litmus paper (~10 pieces per student)

Notes

Probable timing - 120 minutes laboratory time

This introduces the technique of back titration. Being a rather more complicated procedure it leaves rather more scope for student error, hence it is excellent for assessing their technique, considering both their final result and the variation between different determinations. The brighter students will have the sense to save time by doing the standardisation titrations whilst waiting for the ammonia to boil off.

Investigation 12 FINDING THE PERCENTAGE OF LEAD IN SOLDER

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

2 x 250 cm³ conical flask
50 cm³ measuring cylinder
Filter funnel
Filter paper

also generally available

Top pan balance reading to 0.01 g
Oven at ~130°C

Chemicals required

Solder (~10 g per group)
2 mol dm⁻³ nitric acid (100 cm³ per group)
2 mol dm⁻³ sulfuric acid (55 cm³ per group)

Notes

Probable timing - 60 minutes laboratory time

This is included as an example of using a gravimetric technique for analysis. It is fairly simple and straightforward, so should yield good results.

It does however need to be spread over a number of lessons. The solder should be mixed with the nitric acid and left overnight to react (preferably in a fume cupboard). The bulk of the practical can be carried out in the next lesson, but the final weighings are most likely better left until the filter paper has dried overnight in the oven.



Investigation 13 OBSERVING EMISSION SPECTRA

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

The laboratory will need to be blacked out for this practical to be really successful.

Apparatus required (per group)

Hand held spectroscope
2 x watch glass
Nichrome wire
Bunsen burner

also generally available

Gas discharge tubes (sodium, neon, argon, mercury, hydrogen etc.)

Chemicals required

About 10g in total of each of the following solids:

sodium chloride
potassium chloride
calcium chloride
barium chloride
copper(II) chloride
lithium chloride
strontium chloride

Dilute hydrochloric acid ($\sim 10 \text{ cm}^3$ per group)

Notes

Probable timing - 60 minutes laboratory time

This is a qualitative look at emission spectra from various sources. The Data Analysis part of this is a little questionable as it refers more to background theory than to the interpretation of the results obtained, so you may feel more comfortable limiting assessment to just Data Collection. If you have a few brighter students, you could ask them to further research the results they obtain for fluorescent lights as a little piece of more genuine Analysis? Also, if the Physics department has a calibrated spectroscope that allows measurement of the wavelength of lines, then you could add a quantitative exercise to the end of this practical.

Investigation 14 SOME REACTIONS OF THE HALOGENS (Group 17)

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

6 x test tube
3 x boiling tube
watch glass

Chemicals required:

About 10 cm³ per student of:

Aqueous sodium hydroxide
Dilute sulfuric acid
Chlorine water
Bromine water
Aqueous lead nitrate
Aqueous silver nitrate
Iodine in aqueous potassium iodide
Ethanol
Hexane

About 50 cm³ per student of:

Aqueous sodium chloride
Aqueous sodium bromide
Aqueous sodium (or potassium) iodide

Iodine (about 1 g per student):
Blue litmus paper

Notes

Probable timing - 90 minutes laboratory time

A few simple test tube reactions to investigate properties of the halogens that the students should be aware of. Iodine is expensive, so if you prefer, part 1 could easily be done as a demonstration. Parts 2 and 3 rather involve the concept of equilibrium, so be warned if you have not yet introduced it. In part 4 a good test of the thinking student is whether they explain why the non-aqueous solute is added. Don't forget to relate part 5 to black and white photography. I have omitted the differential solubility of the silver halides in ammonia as the syllabus specifically excludes it, but you may want to add it in for fun. The solubility of the lead salts (part 6) is not really necessary, but the iodide is very pretty as it recrystallises and the fact that the bright yellow iodide surprisingly produces a totally colourless solution is a good test of observation. Ask the bright ones why?

Investigation 15 STRUCTURE AND PHYSICAL PROPERTIES

Day/Date of lesson _____ Period - ____ Room _____

Teacher _____ No. of students/groups _____

As with all student-planned practicals, it is difficult to list precisely what the precise requirements will be, but the following are probably a reasonable guess!

Apparatus required

A supply of test tubes, boiling tubes and ignition tubes
Power packs, with electrodes and a light bulb or ammeter in series
Small beakers, watch glasses, petri dishes, evaporating basins

Chemicals required

The students will require a range of unknown solids to test (~ 5 g per student), labelled only with a letter.

A possible list of suitable solids is given below:

- A Silicon dioxide
- B Sucrose
- C Sodium chloride
- D Iodine
- E Charcoal
- F Paraffin wax
- G Calcium carbonate

Notes

Probable timing - 60 minutes planning, 60 minutes laboratory time

I would use this after having dealt with the theory of the way in which bonding affects physical properties, saying to the students, OK, try it in practice. The only thing they may want to do, that I would dissuade them about is testing the electrical conductivity of the molten samples. I simply say that if it is ionic then, with our apparatus we would not be able to heat it to its melting point anyway. Setting some sort of time limit is useful, otherwise you will find some students wanting to take the precise melting and boiling points of things, rather than going for "ball park" estimates.

They will of course find that they will have ambiguities in their results, for example differentiating between an insoluble ionic substance and one with a giant covalent lattice and also the fact that some molecular covalent substances (e.g. sucrose) are more soluble in water than non-polar solvents. However this gives students a chance to weigh up the relative merits of the conflicting pieces of knowledge and reflect on ways in which the uncertainty could be resolved.

Investigation 16 FORCES BETWEEN PARTICLES

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

6 x Test tubes
2 x 10 cm³ measuring cylinders
Accurate thermometer (0 - 50°C by 0.2° divisions?)
Stirring rod

Chemicals required

About 2g per group of the following solids:

Sodium chloride
Urea
Naphthalene
Silicon dioxide

About 5 cm³ per group, except where indicated otherwise, of:

Ethanol (clear meths)
Ethyl ethanoate (ethyl acetate)
Propanone (acetone)
Trichloromethane (chloroform)
Hexane (~50 cm³ per student)
Hexene

Other Requirements

Three long, sealed tubes (0.5 m?) almost filled with liquid, but containing a small air bubble. The liquids should be with hexane, paraffin & propan-1,2,3-triol (glycerol). The tubes should be labelled with the liquid they contain.

Five burettes in a fume cupboard, containing water, cyclohexane, propanone (acetone), tetrachloromethane (carbon tetrachloride) and trichloroethane (chloroform). There should be five large beakers for the liquid from the burettes to run into, as well as supplies of the liquid to top up the burettes. A number of electrostatics rods, and cloths for charging them, will also be required.

Notes

Probable timing - 60 minutes laboratory time

This practical provides a chance to see whether students are capable of applying the concepts of forces between particles to explain some simple observations.

For part 4, it is probably best to have one set of burettes and liquids already set up in the fume cupboard and devise a roster for the students to use these.

Investigation 17 CHANGES OF STATE

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

2 x test tube
2 x boiling tube
2 x thermometer (0 - 110°C)
10 cm³ measuring cylinder
Water bath
Quickfit apparatus for distillation with a thermometer
Buchner flask fitted with bung and a thermometer to go in the liquid
Filter pump

also generally available

Balance capable of weighing to at least 0.01 g

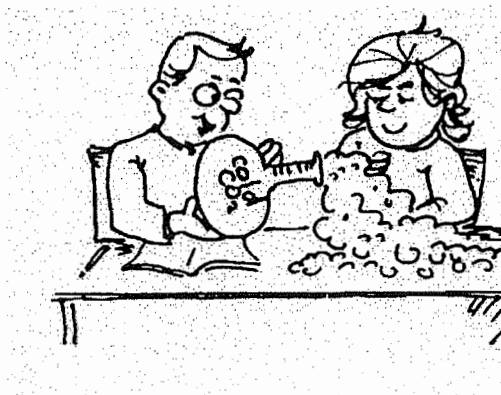
Chemicals required

Naphthalene (~10 g per group)
Methanol (~55 cm³ per group)

Notes

Probable timing - 90 minutes laboratory time

This practical allows students to observe that the temperature remains constant during changes of state. It also allows an estimate to be made of the latent heat of fusion, a concept that students are sometimes less familiar with, assuming that the rate of heat loss from a tube of water and a tube of naphthalene are the same under the same conditions. In the second part, the small volume of methanol is deliberate so that the temperature should remain constant until it has all boiled off, after which it should rise to that of the water bath. The final section allows students to observe the dependence of boiling point on pressure.



Investigation 18 MEASURING MELTING AND BOILING POINTS

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

Melting point apparatus

Boiling point apparatus

Chemicals required

Solids for MP determination, suggestion:

Naphthalene, labelled "Solid A"

Naphthalene ground up with about 5% benzoic acid, labelled "Solid B"

Liquid for BP determination labelled 'Liquid C', (suggestion-methanol)

Notes

Probable timing - 15 minutes planning, 45 minutes laboratory time

Using this for Planning A is probably stretching things a little, but trying to amass enough that test this aspect is not easy! Filling in the planning section should be a fairly trivial exercise for most students, and it can be done either at the same time as the practical or beforehand. Because of the variety of different pieces of apparatus used in different schools to determine melting and boiling points, I have left this open, so that you can demonstrate the correct use of the apparatus you have available to the students. You can then see from the methods they produce, to what extent they were listening to you!

Investigation 19 MEASURING ENTHALPY CHANGES

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus required (per group)

Thermometer (0 - 110°C)
Stop watch
100 cm³ measuring cylinder
Weighing bottle
Polystyrene cup
Electric stirrer

also generally available

Balance capable of weighing to at least 0.01 g
Paper towels
Kettle(s)

Chemicals required

Ice (~25 g per group)
Aqueous 1 mol dm⁻³ copper sulphate (~50 cm³ per group)
Powdered zinc (~5 g per group)

Notes

Probable timing - 60 minutes laboratory time

A fairly straightforward thermochemistry practical that gives reasonably good results. Thermochemistry practicals in my experience tend to give notoriously poor results and so I would assess Manipulative Skills on the *relative* accuracy of the final results. The latent heat generally gives better results than the enthalpy of reaction and there are less embarrassing questions about whether one should take into account the specific heat of zinc, copper, or both!

Investigation 20 USING HESS' LAW TO DETERMINE ENTHALPY CHANGES

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus (per group)

Thermometer (preferably 0 - 50°C by 0.1°C intervals)

Stop watch

100 cm³ measuring cylinder

Weighing bottle

Polystyrene cup (at least 250 cm³ capacity)

also generally available

Balance reading to 0.01 g

Chemicals required

2 mol dm⁻³ hydrochloric acid (~250 cm³ per group)

Solid sodium hydrogencarbonate (bicarbonate) (~15 g per group)

Solid anhydrous sodium carbonate (~10 g per group)

Notes

Probable timing - 60 minutes laboratory time

Another thermochemistry practical, this time one that allows students to put Hess' law into practice. The results are even more unreliable however as heat losses occur through the gas evolved. I have deliberately not included graph paper, but the students are told to use extra paper if required and if, in view of the data collected, these did not include some graph paper, it would certainly be reflected in my Data Analysis mark.

A photocopyable graph page is provided in the front of the Portfolio.

Investigation 21 TECHNIQUES FOR MEASURING REACTION RATES

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus (per group)

Stop watch
100 cm³ measuring cylinder
50 cm³ measuring cylinder
25 cm³ measuring cylinder
10 cm³ measuring cylinder
2 x 250 cm³ conical flask
Burette
10 cm³ pipette and pipette filler

At least one set of

250 cm³ conical flask fitted with a bung connected to a 100 cm³ gas syringe
Spectrophotometer or colorimeter

also generally available

At least two balances reading to 0.01 g
Filter paper

Chemicals required

0.5 mol dm⁻³ hydrochloric acid (~50 cm³ per group)
2 mol dm⁻³ hydrochloric acid (~60 cm³ per group)
2 mol dm⁻³ nitric acid (~100 cm³ per group)
0.005 mol dm⁻³ iodine dissolved in 0.1 mol dm⁻³ KI (~25 cm³ per group)
2 mol dm⁻³ aqueous propanone (~50 cm³ per group)
0.005 mol dm⁻³ aqueous sodium thiosulphate (~250 cm³ per group)
0.02 mol dm⁻³ aqueous sodium thiosulphate (~20 cm³ per group)
sodium hydrogen carbonate (~25 g per group)
Magnesium ribbon (~4 cm per group)
Marble chips (~10 g per group)
Starch indicator

Notes

Probable timing - 120 minutes laboratory time

This practical is designed to allow the students to become familiar with a variety of techniques that can be used for monitoring the rate of a chemical reaction. It is deliberately open ended from the point of view of data recording and result analysis and again, even though a graph proforma is not provided in this practical, I would be most unhappy if students did not produce graphs, with suitably drawn tangents, of their results. A photocopiable page is provided in the front of the Portfolio. The sensible use of equipment with which they have had little previous experience, such as the gas syringe and spectrophotometer/colorimeter, should allow an assessment of Manipulative Skills.

Investigation 22 AN INVESTIGATION OF THE EFFECT OF CHANGING CONDITIONS ON REACTION RATE

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus and chemicals required

As with any student planned practical, it is difficult to be precise about the requirements. If the students have recently completed the practical on "Techniques for Measuring Rates of Reactions" then it is probable that their requirements will be quite similar to those for that practical.

Notes

Probable timing - 60 minutes planning, 90 minutes laboratory time

This is a good practical to carry out immediately after Investigation 21, so that students tend to choose one of the reactions investigated there and all the apparatus is still out. They are left free to decide what they are going to vary, but it is worth noting, for the sake of all those who think rate is proportional to temperature, that they are only asked to formulate a hypothesis, not a correct hypothesis! As the technique will probably closely mirror one of those in the previous investigation, Planning (b) marks will probably focus on choosing a suitable range for the manipulated variable and adequate control of the other variables.



Investigation 23 FACTORS AFFECTING THE RATE OF A CHEMICAL REACTION

Day/Date of lesson _____ Period - _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus (per group)

250 cm³ conical flask

50 cm³ measuring cylinder

0 - 110°C thermometer

Top pan balance accurate to 0.01 g (preferably one per group)

Chemicals required:

~5 mol dm⁻³ hydrochloric acid (about 100 cm³ per group)

Small lumps of calcium carbonate (about 20 g per group)

Large lumps of calcium carbonate (about two ~10 g lumps)

Notes

Probable timing - 90 minutes laboratory time

A fairly straightforward practical that looks at the effect of most variables, except the presence of a catalyst, on the rate of reaction. If the students were to do all the parts of it themselves it would take a long time, so I usually ask them all to do Part A (just so they can see how varied the results are!) and I then assign them one of the other parts. They can then share results at the end - Personal Skills (a)!

As the students do not look at the effect of a catalyst here, I often do a demonstration of the effect of a catalyst either during the practical or another lesson close to it. The "pink foam" (see Investigation 3) is always worth repeating, but I must admit my favourite (although it prompts a lot of difficult-to-answer questions) is the catalysis of the reaction between sodium potassium tartrate (Rochelle's salt) and hydrogen peroxide:

Take about 4 spatulas of the tartrate and dissolve it in about 20 cm³ of 20-volume hydrogen peroxide, then divide the solution equally between two boiling tubes. Heat the first one and note that it has to be almost boiling before there is any sign of reaction. Add a couple of crystals of cobalt(II) chloride to the second, swirl until these dissolve and then warm gently. Note that gas starts to be evolved when it is still cool enough to hold. The colour changes, showing that the cobalt is involved in the reaction, but changes back to the original pink at the end, showing that it has not undergone any permanent change.

Investigation 24 AN INTRODUCTION TO EQUILIBRIUM

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus (per group)

100 cm³ measuring cylinder
10 cm³ measuring cylinder
4 x 100 cm³ beaker

Chemicals required:

0.02 mol dm⁻³ aqueous potassium thiocyanate (~100 cm³ per group)
0.01 mol dm⁻³ aqueous iron(III) nitrate (~20 cm³ per group)
Solid potassium thiocyanate
Solid sodium fluoride

Notes

Probable timing - 30 minutes laboratory time

I usually do this as a demonstration and put the four beakers on top of the overhead projector so that the colours are easy to compare. In that way I can ensure that the students fill in each section before going on to the next. They naturally think it is a normal reaction in which the iron(III) is the limiting reagent and become rather agitated when their prediction, that adding extra thiocyanate will have no effect, proves to be incorrect!



Investigation 25 PREDICTING THE EFFECT OF CHANGES ON AN EQUILIBRIUM

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus

This will vary according to students' plans, but will probably involve a selection of:

- Burettes & burette funnels
- Pipettes & pipette fillers
- Volumetric flasks
- Measuring cylinders
- Conical flasks
- Beakers
- Filter funnels and paper
- Evaporating basins
- Test tubes and boiling tubes

also generally available:

- Top pan balance reading to 0.01 g
- pH meters

Chemicals required

This will be very dependent upon what the students request.

Notes

Probable timing - 45 minutes planning, 45 minutes laboratory time

A chance for the students to plan a practical giving a qualitative demonstration of "Le Chatelier's Principle". I usually have students plan the practical, and hand in their plan, before carrying out the practical, so I can check them for practicability, safety etc., as well as ordering suitable reagents. Obviously it would be very easy to assess this for other criteria, such as Data Collection, Data Analysis and Evaluation, as well as the Planning criteria, but my personal preference is to have a limited number of focuses for each investigation

Investigation 26 A COMPARISON OF STRONG AND WEAK ACIDS AND BASES

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus (per group)

6 x Test tubes
4 x Boiling tubes
10 cm³ measuring cylinder
100/150 cm³ conical flask
Burette and funnel
Burette clamp
Burette funnel

also generally available

Conductivity apparatus

Chemicals required

1 M hydrochloric acid (~100 cm³ per group)
1 M sulfuric acid (~100 cm³ per group)
1 M nitric acid (~100 cm³ per group)
1 M ethanoic acid (~100 cm³ per group)
0.1 M hydrochloric acid (~100 cm³ per group)
0.01 M hydrochloric acid (~100 cm³ per group)
1 M aqueous sodium hydroxide (~100 cm³ per group)
0.1 M aqueous sodium hydroxide (~20 cm³ per group)
0.01 M aqueous sodium hydroxide (~20 cm³ per group)
1 M aqueous ammonia (~20 cm³ per group)
Marble chips (~6 per group)
Magnesium ribbon (~6 x 2 cm lengths per group)
Copper(II) oxide (~2g per group)
Narrow range pH paper (a selection to cover pH 0 to pH 14)
Phenolphthalein indicator

Notes

Probable timing - 120 minutes laboratory time

This is a rather lengthy practical as it combines an investigation of the properties that all acids have in common with the differences between strong and weak acids and bases. As conductivity equipment varies I have not included specific instructions, so you will probably have to demonstrate the use of the apparatus available to the students before they start. In parts 1) and 3) I specify the use of narrow range pH paper rather than a pH meter, because for the purpose required I find it just as accurate and simpler, not to mention the fact that glass electrodes may not perform accurately with concentrated alkali. A pH meter could however be used, if you prefer it.

Investigation 27 COMMON OXIDANTS AND REDUCTANTS

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus (per group)

- 6 x Test tubes
- 2 x Boiling tubes
- 2 x Splints

Chemicals required

About 10 cm³ of each of the following aqueous solutions per group.

- Aqueous iron(II) sulphate (Fresh solution)
- Aqueous copper sulphate
- Aqueous sodium hydroxide
- Aqueous potassium iodide
- Aqueous potassium dichromate(VI)
- Aqueous potassium permanganate(VII)
- Aqueous ethanedioic (oxalic) acid
- Dilute hydrochloric acid
- Dilute sulfuric acid
- Hydrogen peroxide
- Aqueous chlorine solution
- Aqueous sulfur dioxide solution
- Limewater
- [Concentrations are not too important.]

- Granulated zinc
- Magnesium ribbon
- Calcium metal

Notes

Probable timing - 90 minutes laboratory time

A simple series of reactions to familiarise students with a variety of oxidising and reducing agents. In the space for the equations I have left three lines so that the students can write the relevant half equations before combining them, though of course they could produce the balanced equation by other methods if you prefer.

If you like demonstrations, there are a number of fairly spectacular redox demonstrations such as the "Thermit" reaction (powdered Al & Fe₂O₃, ignited by a fuse of Mg ribbon), or the formation of aluminium iodide (powdered Al & I₂, activated by a few drops of water) - both can be a bit hazardous so *check out details in a book* of demonstration reactions.

My favourite however, because of its simplicity is just to make a crater in a small mound of finely ground potassium permanganate(VII) on a steel plate and pour in a little glycerol. It takes a few seconds to start, but then there are lots of impressive lilac flames!

Investigation 28 SOME REACTIONS OF HYDROCARBONS

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus (per group)

6 x test tubes with corks/bungs
Watch glass or evaporating basin

also generally available:

Splints

Chemicals required

Cyclohexane (~10 cm³ per student)
Cyclohexene (~10 cm³ per student)
Methylbenzene (toluene, ~10 cm³ in total)
Bromine water (Freshly prepared, ~5 cm³ per student)
Aqueous ammonia (~10 cm³ in total)
Aqueous acidified potassium permanganate (~5 cm³ per student)
(dilute sulfuric acid with just enough permanganate to make it purple).

Unknown organic compounds, labelled with a letter - to be chosen by the teacher
(suggestions would be gas from the gas tap, olive oil, paraffin, ethanal).

Notes

Probable timing - 60 minutes laboratory time (including planning time)

A number of fairly simple reactions of hydrocarbons coupled with testing some unknowns for saturation. I include the reaction with permanganate for two reasons - firstly because the colour remains in the aqueous layer as a contrast to bromine (revise intermolecular forces). Secondly it emphasises that both it and the bromine are reduced in the addition reactions and so the test for unsaturation would not be valid if other groups that acted as reducing agents were present.

Investigation 29 INVESTIGATING ORGANIC STRUCTURES USING MODELS

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus (per group)

One molecular modelling kit, containing at least:

6 carbon atoms

10 hydrogen atoms

2 oxygen atoms

2 chlorine atoms

12 single bonds

2 double bonds

Notes

Probable timing - 60 minutes

A chance for students to play with models in order to realise the limitations of two dimensional structural formulae. It goes well beyond the SL syllabus, but I do all of my isomerism at one go, hence the HL work. If you cut this out then it will probably take less time, if you include it then it may take a little longer. You can extend the Manipulative Skills assessment to returning the kit complete and not throwing the balls around!



Investigation 30 THE PREPARATION OF A LIQUID ALKENE

Day/Date of lesson _____ Period _____ Room _____

Teacher _____ No. of students/groups _____

Apparatus (per group)

Quickfit apparatus for distillation with thermometer

Test tube

100/150 cm³ beaker

2 x 250 cm³ beaker

0-110°C thermometer

10 cm³ measuring cylinder

Chemicals required

Concentrated sulfuric acid (~10 cm³ per group)

2-methylbutan-2-ol (tertiary amyl alcohol, ~15 cm³ per group)

Bromine water

Ice

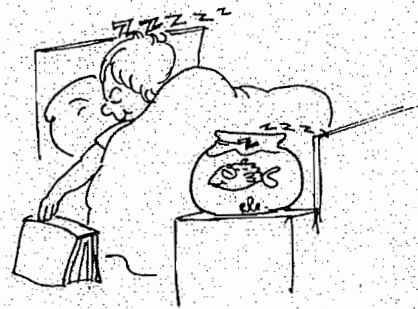
Aqueous sodium hydroxide solution

Anhydrous calcium chloride

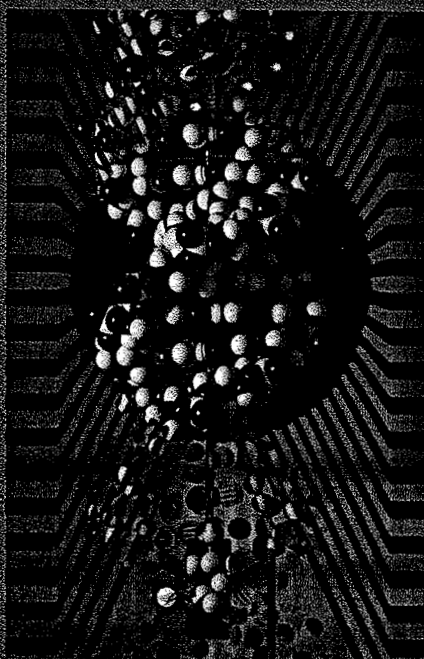
Notes

Probable timing - 120 minutes laboratory time

I like preparative chemistry as students seem to gain a certain satisfaction from having something they have made (sort of like cooking!). I think it also requires a different type of Manipulative Skill. This Investigation is generally fine, though on occasions I have had good students end up with poor yields for no obvious reason. I often don't get as far as the final stages and leave it at just the crude product. If you continue with the purification, you may find it works better if students combine their crude products, so they are working with a larger volume. You may also find you need quite a lot more time!







A Portfolio of Investigations Chemistry

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